THE GLASS INDUSTRY

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MANUFACTURE OF STRUCTURAL GLASS

Works No. 6 of the Pittsburgh Plate Glass Co., Ford City, Pa., produces the line of opaque, colored plate known as Carrara glass, and also heavy, polished plate most of which is for the famous Herculite. Plant operations are characterized by a wide range of batches and products.

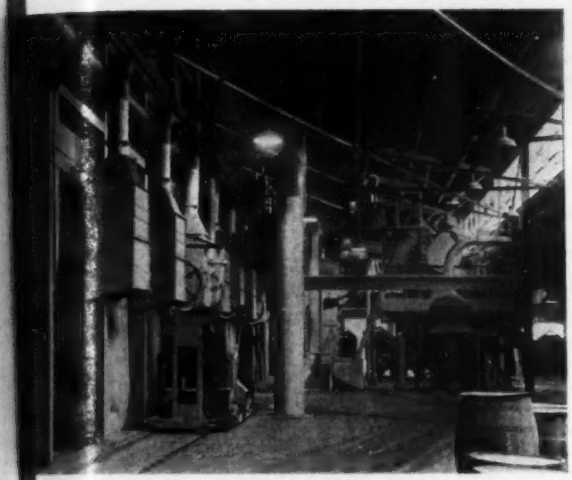


Fig. 1. In this view of the mixing house of the Pittsburgh Plate Glass Co. plant at Ford City, the bulk material bins are at the left and the mixing machinery in the background. Note the dust-hooded bin chutes and the traveling weigh-car.

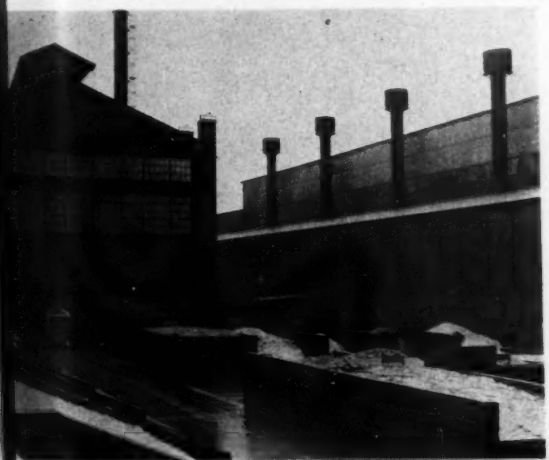


Fig. 2. Many kinds of Carrara cullet are stored in large open bins in the yard between the mixing house and the casting hall.

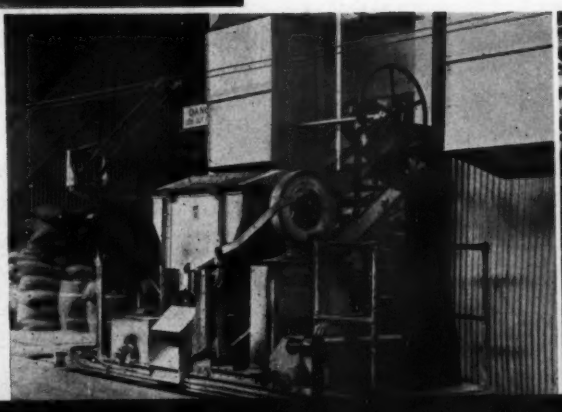


Fig. 3. A closer view of the batch weigh-car shows how the bin gates are operated and the chute through which the weighed materials are discharged into the skip-hoist at the mixer.

At first glance the activities in Works No. 6 of the Pittsburgh Plate Glass Co., Ford City, Pa., seem to follow the usual pattern of operation for the casting and finishing of plate glass from pots, but closer inspection brings out details of procedure which show that the complicated technique is just as unusual and interesting as the products which it manufactures. The complexities of operation stem from the wide range of glasses produced and from the great variation in thickness of the rolled plate. The major portion of the tonnage goes into so-called structural glass, such as the colored Carrara and heavy polished plate.

In recent years opaque colored plate glass has become practically a staple architectural item and is familiar to the ordinary citizen from its use in the decoration of store fronts and other public and semi-public buildings. Such plate is polished on one side only, but in heavier thicknesses it is also used for inside partitions, for which application it is ground and polished on both sides. Pittsburgh Plate's Carrara is furnished in ten standard colors, five of which—white, black, ivory, jade and gray—are produced in five different thicknesses ranging from $^{11}/_{32}$ in. to $1\frac{1}{4}$ in. The other five colors —green, blue, orange, wine and beige—are available in one thickness each.

The other big tonnage item at Works No. 6 is transparent, polished plate of first quality, a great deal of which goes into the now well-known Herculite which is being increasingly used for doors, furniture and other architectural details. This plate is made in eight thicknesses, from $^{5}/_{16}$ to $1\frac{1}{4}$ in. Other minor complications

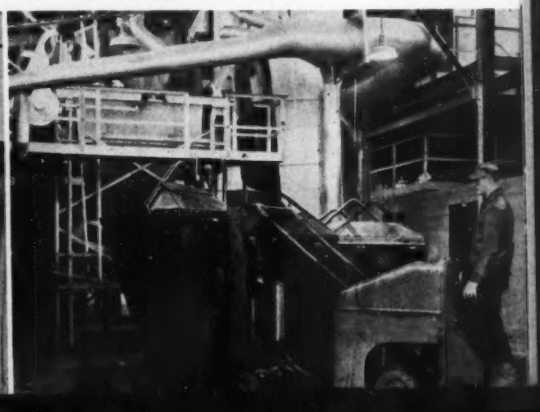
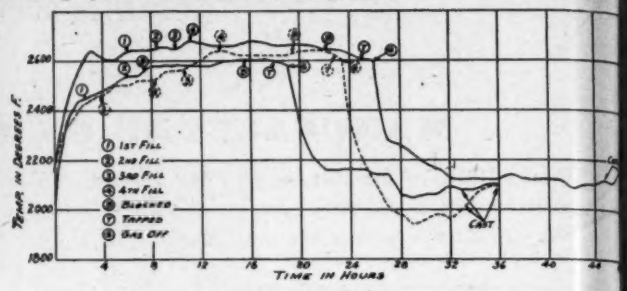


Fig. 4. Mixed batch is transported to the furnace room in unit containers by industrial trucks. Note the hooks near the top of the bucket by which it hangs on the rail of the truck frame. In the background can be seen one of the skip-hoist housings and the dust piping around the mixing equipment.

Fig. 5. Four of the eight regenerative furnaces in the casting hall appear in this view. The furnaces are fired by natural gas which enters through piping that can be seen at the far left.

Fig. 6. Curves plotted from actual charts showing the pot-heating cycles for three different glasses.



are inserted by such specialties as colored mirror plate, blackboard plate, special X-ray resistant glass, and heat-absorbing plate glass.

To the average glass plant operator, concerned with the making of one or a few glasses in large quantities or with a variety of glasses in small quantities, the manufacturing problems at Works No. 6 seem quite appaling, but this experienced plant organization seems to take all the hurdles in its stride. Each thickness of the opaque Carrara, except black, requires a different batch, so there are some eighty batches to be mixed in order to care for the fifty or so glasses. Then, each glass has a melting cycle to suit its particular requirements in the furnace, and the annealing cycle must be varied also for various colors and thicknesses of glass passing through the lehr. The involved operations extend even to the grinding and polishing line which must accommodate the wide range of thicknesses and finish one or both sides of the sheet as required. The plant has capacity for around 75 tons of finished glass per day, so it is apparent that good management is needed to keep inventories of raw materials and rough and finished plate within bounds, as well as to maintain close limits of color and quality.

A total of forty-eight batch materials are regularly carried in stock and the job of always having a sufficient quantity of all these ingredients on hand for the considerable tonnage of glass melted presents no small problem. All of the usual glass-making materials are included in the list, together with many coloring oxides, anthracite screenings, pulverized clay, precipitated calcium carbonate, and various compounds of aluminum, barium, cerium, iron, potassium, rare earth, sodium and zirconium. Some of the coloring oxides for Carrara glass are used in exceedingly small amounts and these very minor ingredients are weighed out in the laboratory to obtain the necessary accuracy. In Carrara gray, for instance, three coloring oxides are used in the proportions of 0.002, 0.029 and 0.016 per cent, these being equivalent in a 2,600-lb. batch to 0.83, 12.06 and 7.61 ounces, respectively. The deeper colors, of course, use coloring oxides in greater proportions, ranging up to about 0.20 per cent. Opacity in the colored glass is secured by the use of fluorspar or sodium silico-fluoride.

In the mixing building nineteen bins for the storage of major batch ingredients are arranged in two sections, of twelve and seven bins, respectively, along one side of the building. The mixing machinery is located on the floor of the house at the farther end of the seven-bin section, as shown in Fig. 1, and an electrically-operated weigh-car runs on a track beneath the discharge spouts of the bins. Incoming railroad cars are spotted on a siding along the outside wall of the building and are unloaded into an elevator hopper by means of a power shovel. The elevator rises in the space between the two

Fig. 7. The first step of the casting operation. The pot of melted glass is withdrawn from the furnace by a heavy fork carried on the big traveling crane.

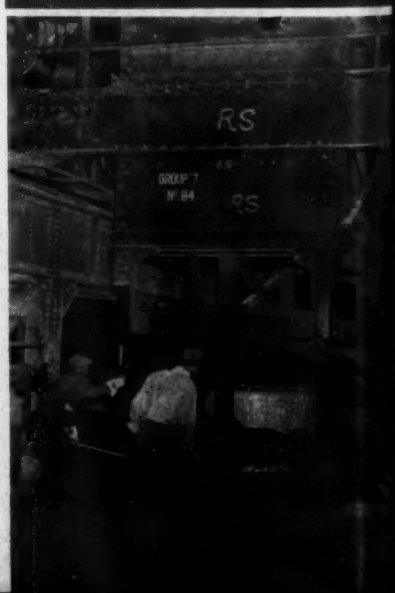


Fig. 8. The pot of glass which has been placed on a pedestal by the crane is now gripped by the jaws of the ponderous manipulating mechanism. Immediately to the rear can be seen the brushes which remove debris from the bottom of the pot and the rolling machine and control booth are farther along.

Fig. 9. The pot has arrived at the rolling machine and its contents are being poured into the machine. The molten glass appears perfectly black in this flashlight picture.

bin sections and discharges on a shuttle belt conveyor that can be located to empty into any bin except the first four, which are reserved for cullet. Each bin has a capacity of about 60 tons.

The cullet bins hold black, white, and clear cullet, respectively, and are served by three cullet elevators from three crushers in the basement. Other cullets in large quantities are stored in open bins in the factory yard, between the mixing house and the furnace building, as shown in Fig. 2, and small-quantity cullets are kept in covered bins on the mixing-house floor. The proper segregation of cullets is a very important factor and every care is taken to keep the cullet clean and to avoid any mixing of different kinds. A portable crusher serves the cullet storage in the yard.

Of the 15 remaining bins in the mixing-house, four are used for one grade of sand and two for another; four contain feldspar; two hold limestone; two are for soda ash; and one contains fluorspar. Each shipment of incoming material is segregated and is then analyzed before use, the batch formula being changed, if necessary, to conform with the actual analysis of the material. For the lighter colored glasses the iron content of the feldspar and sand is kept very low, running an average of 0.02 per cent, and down to 0.015 for the spar and 0.011 for the sand. Major batch ingredients are collected in the weigh car shown in Fig. 3, the minor constituents being weighed either in the laboratory or on small scales in the mixing house. Each bin spout is fitted with a rack-and-pinion gate operated by a large handwheel and is covered by a dust hood that is connected to a central exhaust system. Materials are collected in the weigh hopper in rotation and are then discharged through a lever-operated gate into a skip-hoist at the mixer.

The mixing equipment incorporates three mixers, two of the drum type and one of the dry-pan type, all equipment being covered by dust hoods that connect to the central exhaust system. One of the drum-type mixers is reserved for black glass. All the other glasses made in the plant are mixed in the dry-pan type mixer which is comparatively easy to clean and seems to be well adapted for this work. Each mixer discharges to a magnetic belt conveyor which, in turn, delivers the mixed batch to individual batch buckets, each batch weighing in the neighborhood of 2,600 pounds.

Loaded batch buckets are picked up by electric trucks, as illustrated in Fig. 4, and transported to the furnace building. Each bucket has two heavy hooks near the top, by which it hangs from a rail on the front of the truck while being transported and from a similar rail at the front of the furnace while the pots are being filled. A heavy bail at the top of the bucket permits handling of the mixed batch by the furnace room crane. In the background of Fig. 4 can also be seen one of the skip-hoist housings and the dust piping about the mixing equipment.

Four of the eight regenerative furnaces in the big casting hall are shown in Fig. 5. All furnaces are fired by natural gas. The regenerative furnaces accommodate twelve pots each. In these furnaces air checkers lead to one large port at each end, the fuel gas being fired through two holes in each end wall, as shown in the illustration, and the air being reversed by the usual type of cast-iron reversing valve in the basement. The three large openings at each side of the furnace are covered by large refractory doors, each opening accommodating two pots. The doors are raised and lowered for the entrance and removal of the pots by a power-operated system of pulleys and chains.

In most plate-casting shops it has always been customary to place the responsibility for the proper melting of the glass on one man who followed the finishing of the glass all the way through, but under present

Fig. 10. Looking down the driving side of the annealing lehr from the rolling-machine end. The tunnel is 440 ft. long and natural gas is used for fuel. The complicated driving mechanism can be seen on the floor.

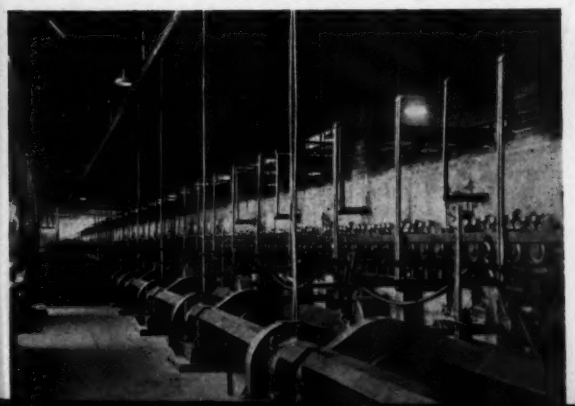


Fig. 11. Rough annealed sheets passing along the open section of the lehr conveyor beyond the end of the tunnel. The entrance to the trimming and cutting room can be seen in the distance.

Fig. 12. The sheets are trimmed and cut into pieces, 74 x 131 in., and are then raised on this vacuum-cup frame and placed on racks for transportation to the grinding and polishing line.

Fig. 13. Here the rough sheet has just been placed in its plaster bed on one of the grinding tables. The vacuum-cup frame will now be removed and the squeegee rollers in the background will pass over the sheet, bedding it into the plaster.

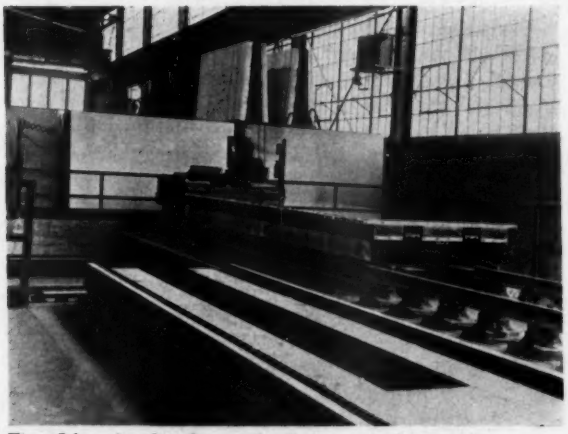


Fig. 14. At the far end of the grinding and polishing line the heavy tables are transferred to the return track by this electrically-operated car. There is a similar car at the other end of the line.

wages and hours legislation such procedure cannot be followed, especially in a plant where the total production is large as well as varied. At Works No. 6, therefore, a heating schedule for each furnace is planned carefully in advance and the written schedule is posted at each furnace for the guidance of the furnace operators. Furnace temperatures are recorded continuously by instruments at each furnace, the thermocouple being located just beneath the crown at the center.

Casting operations are begun at 12-hour intervals, at 7 A. M. and 7 P. M., so the pot heating schedules have a duration of either 36 or 48 hours, depending on the type of glass. Fig. 6 shows the actual time-temperature curves for three different glasses, one of which has a 48- and the others 36-hour schedules. These curves are an indication of the complexities of furnace operation in a big plant of this type. Each glass must not only be melted in accordance with its own rather rigid requirements, but its production must be fitted into the general plant operation, thus presenting a nice problem in production planning when such factors as change in batch with glass thickness, different lengths of pot cycles, and inventories, are considered.

After the pot has been cast and replaced in the furnace, the temperature is raised and the filling of batch is completed in three or four stages during the next 12 hours, as shown in Fig. 6. The furnace is then held at the required melting temperature for a given period until the glass is melted and the emission of gas begins. All pots are blocked at this point to hasten the elimination of gas, wood blocks being used for reduced glasses, polished plate, etc. Other glasses are blocked with chemical pills, arsenic oxide being used for the Carrara. When the glass is nearly finished the furnace is tapped, this operation being the opening of a hole at the bottom of the furnace door, or tuile, through which accumulated slag, and glass that adhered to the pot from the previous cast or was caused by spilled batch, is allowed to run out of the furnace.

The gas is finally turned off the furnace about an hour later. The temperature is usually allowed to drop to a point somewhat below the casting temperature and held at that point until about six hours before the cast, when the temperature is raised to the proper point for casting the particular glass.

The casting operation is quite a spectacular proceeding, especially in the early morning or late evening when the flashes of light from the opened furnace doors, the hot pots and the molten glass, light up the gloomy recesses of the big casting hall. It is a matter of good teamwork, aided by a lot of ingenious special machinery, most of which has been developed by Pittsburgh Plate engineers. Figs. 7, 8 and 9 show successive stages in the casting of a pot of black glass. As soon as the preceding cast has advanced far enough into the lehr to permit the entrance of another sheet, a whistle is blown and the big traveling crane positions the heavy pot tongs in front of the furnace door, which is then raised. Guided by the hands of an operator, the fork is placed

Fig. 15. A view in the cleaning and inspection room. Note the highly polished surface of the black glass sheet at the left which has just come from the grinding and polishing line.

in position on the pot and it is carefully raised and withdrawn from the furnace, as shown in Fig. 7.

Without delay the scintillating pot of glass is rushed up through the casting hall and placed on a pedestal near the rolling machine, after which the crane tongs are removed and the ponderous manipulating machinery is moved over the pot by the operator in his glass-enclosed cubicle beyond the rolling machine, as shown in Fig. 8. The jaws of the manipulator are quickly clamped on the pot and it is then transported a few feet toward the rolling machine where a set of revolving brushes removes debris from the bottom of the pot and the sides are cleaned by air hoses in the hands of attendants. Fig. 9 shows the actual casting operation, in which the contents of the pot are emptied into the rolling machine.

The rolling machine consists of a big roller about seven feet long and the same in diameter, above which a second smaller roller is mounted to one side of the center line of the first. The top of the large roller is about flush with the casting room floor and the space between the faces of the rollers can be adjusted to suit the required thickness of the plate. In Fig. 9 the smaller roller can be seen, but the top of the large roller is hidden by the glass flowing from the pot. In contrast to the usual method of lehr loading, in which the sheet is received on a portable table or car and rolled into the lehr, the freshly rolled sheet from the Pittsburgh Plate rolling machine is carried directly into the lehr on a series of power-driven rollers, the glass entering the lehr at around 1,300° F., or well above the softening point. This procedure effects a very considerable saving of the sensible heat in the glass and tends to speed up the whole process, but it is made possible only by a very ingenious and complicated drive in the front end of the lehr.

Exact cooling curves for all the types and thicknesses of glass have been carefully worked out and the speed of the lehr rollers is set at the beginning of the cast to meet the cooling requirements. This speed is, of course, much slower than the speed at which the glass leaves the rolling machine and enters the lehr. The problem is, therefore, to get the freshly-rolled, comparatively-soft sheet into the lehr at the rolling speed and then to carry it through the tunnel at a speed determined by the cooling gradient, and as close as possible to the preceding sheet. The rollers in a length of the tunnel sufficient to receive the longest sheet produced are, therefore, divided into 13 sections, each group of rollers being driven at either the high or low speed, as required, and the change from one speed to the other being caused automatically by the passage of the glass. Fig. 10 is a view down the driving side of the lehr taken from near the rolling machine end.

When the sheet-rolling operation starts, all the lehr rollers are revolving at the slow speed, but as the front end of the new sheet approaches the lehr the roller speed in the first group is increased to equal the speed of the sheet. As the sheet enters the lehr, each successive section speeds up in turn and the new sheet is carried to within a few feet of the preceding sheet at the rolling machine speed. At this point all the roller groups return to the slow speed and the sheet continues slowly through the lehr.

The lehr tunnel is 440 ft. long and about 9 ft. wide inside, the width of the rolled sheet being approximately 80 inches. An open section at the far end of the tunnel carries the sheet to the trimming and cutting position, as shown in Fig. 11. The lehr is heated with natural gas, heat being applied in flues beneath the tunnel floor and by a series of burners on the floor of the tunnel beneath the rollers. The flue is heated near the center and the products of combustion pass toward stacks at both ends of the lehr. The products of combustion from the burners in the tunnel are drawn to the far end and exhausted by a fan. Temperatures at 90 points in the tunnel are read and recorded every hour. The lehr is very flexible as regards annealing speed, the total variation being from 12 in. to 75 in. per minute.

At the end of the open lehr conveyor section, the big rolled and annealed sheet is trimmed and cut into sections 74 x 131 inches in size. The trimmed sheets are picked up by a vacuum-cup frame suspended from an electric crane, as shown in Fig. 12, and placed on racks in which they are transported either to rough stock or directly to the head of the grinding and polishing line. Except in detail, the grinding and polishing equipment is similar to most modern installations of such machinery. The rough plate is bedded in plaster on heavy tables which pass slowly down a track, carrying the glass beneath the grinding and polishing heads. At the end of the line the tables are transferred to a parallel track and returned to the end of the line from which they started. As they near the end of the return line the ground and polished plates are removed from the tables and either taken to the inspection department, if they are to be ground and polished on one side only, or reversed and again placed on the tables at the head of the grinding line, if they are to be ground and polished on both sides.

Fig. 16. Looking down the center aisle of the finished plate storage toward the finishing department. This is really a colorful sight, since Carrara glass is furnished in 10 different colors.

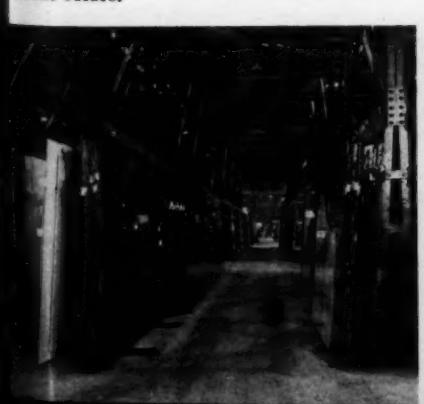
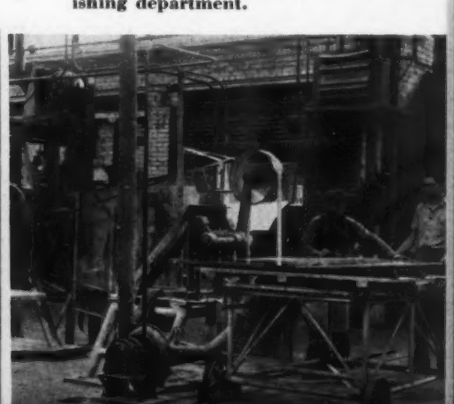


Fig. 17. The first operation in the finishing department is the cutting of the sheet to sizes specified on orders. A corner of the plate storage can be seen in the background at the left.

Fig. 18. The edges of Herculite doors are ground to a slight curvature by a high-speed abrasive belt. This is only one of many edge-grinding operations carried on in the finishing department.



The setting of the rough sheet on the grinding table is illustrated in Fig. 13. Here the suction lifting device is just being released from the sheet, after which the frame in the background will carry squeegee rollers over the sheet to press it firmly into its plaster bed. The loaded tables pass slowly toward the grinders in the background at a speed of from 36 to 38 in. per min., a good view of the 12 grinding heads being shown in the view that appears on the front cover of this issue of THE GLASS INDUSTRY. Between the grinders and polishers the tables pass an open space in which broken pieces are removed, if any, and all cracks are carefully filled with plaster. The surface of the sheet is then polished as it passes under a line of 25 polishing heads, rouge being used for the polishing agent. Sand for the grinders is carefully graded, the larger grains being used in the first heads and the finer material being fed to the later positions.

As the tables leave the polishing heads they approach the end of the track and are picked up by a transfer car, shown in Fig. 14. This car transfers the tables with the ground and polished sheets to the return line and another similar car transfers the tables back to the head of the grinding line at the other end of the hall. As compared with other grinding and polishing operations, it is apparent that this process is comparatively slow, but it has been designed to fit the production of the casting hall and fits well into the general plan. By adding grinding and polishing heads the operation could be speeded up easily, but the department would then be idle a large part of the time waiting for glass.

A view in the area where the ground and polished sheets are cleaned and inspected is given in Fig. 15. An idea of the kind of surface secured can be gained from the reflections in the big sheet of polished black glass on the rack at the left. The inspectors work in a blaze of light from a series of mercury lamps with daylight filters and each plate gets a thorough inspection before it is finally passed along to the finished plate storage. In Fig. 16 you are looking down the center aisle of the storage space toward the finishing department, and it is here that the plant visitor first gets a good eyeful of the beautiful variety of colors in which Carrara glass is made. Of course, the printed halftone gives no indication of the colorful vista that was actually in front of the camera lens, but most readers are already familiar with decorative architectural effects possible with this type of glass.

In the big finishing department the first operation is to cut the polished sheets into sizes required on specific orders. Fig. 17 shows the cutting operation on one of the big cutting tables and a portion of the finished plate storage appears in the background at the left. Glass which does not require any further decoration or edge-grinding passes directly to the final inspection and matching department and from there into the shipping room. In the finishing department are many varieties of grinding machines, built with the precision and accuracy of fine machine tools. The majority of these perform an edge-grinding operation on plates of varying sizes and thicknesses. In this department, also, heavy polished plate is shaped for the famous Herculite doors, the edges of which must be slightly rounded in the grinding operation. This operation is shown in Fig. 18, the grinding machine being fitted with a high-speed abrasive belt.

Another interesting finishing operation is the bending of plates of Carrara glass to fit rounded architectural corners or columns. The decorating department includes a large layout and processing room with the sandblast room, illustrated in Fig. 19, as and adjunct. The sandblast is used for etched decorations and also for cutting the indentations required in inlaid work.

Many people consider the application of colored structural glass for architectural purposes to be a new development, because of the wide increase in its use in recent years. As a matter of fact, it has been used for nearly forty years, most of the earlier applications being on inside work, however. With the exception of such applications as inside partitions made of heavy plates ground and polished on both sides, the plates are fastened in place with a ⅜-in. layer of high-grade mastic cement and the resulting surface stands the wear and tear of weather and use equally as well as any other structural decorative material. No other material provides the depth and variety of color that is possible with glass. however, and it has other peculiar advantages, such as ease of cleaning, density, imperviousness, and a hard surface which retains a fine luster and polish. These inherent qualities account largely for the ever-increasing use of plate glass for building construction and decoration.

Fig. 19. The sandblast room shown here is an adjunct of the decorating department. The sandblast is used for etching and for the actual cutting required for inlaid work.

DOMESTIC GLASS REPLACING IMPORTED MATERIALS IN GERMANY

Substitution of domestically-produced glass wherever possible for metals and other materials which have to be imported is a subject now engaging the attention of German authorities, according to a report from Consul General R. C. Busser, Leipzig, made public by the Department of Commerce.

The use of glass to replace metal is designed to assist the domestic glass industry and to conserve foreign exchange.

Glass wool, known as "angels' hair" and used for Christmas tree ornaments, is being produced in large quantities for insulation purposes, replacing other materials. Many factories are installing glass pipe lines for cooking and heating systems, and it is reported that glass pipes are being installed in private homes.

Because of this development the German glass industry is working at capacity even though exports of glassware have been steadily declining. In some branches of the industry a shortage of labor has been reported, according to Consul Busser.

COMPULSORY LICENSING OF PATENTS

By ERIC H. WATERS

In the January 1939 issue of THE GLASS INDUSTRY, a very interesting and coherent picture was given of the anti-monopoly investigation made by the T.N.E.C., relating to the glass industry. This was one phase of the investigation into the larger subject of monopolies in general.

The subject of patent monopolies has been one of a special interest, and there have been many discussions in legal and business circles, the press, and elsewhere of what many consider to be abuses of the monopolies derived from patents.

It is curious to note how many, and in my opinion ill-founded, views are held that many patents are taken out only to be pigeonholed, and therefore voluntarily not put to any useful purpose. Many believe that this so-called "pigeonholing" should be overcome by a change in the present patent laws to force the patentee to manufacture under his patent, or to grant license to others to manufacture. This is what is usually referred to as a Compulsory License System, and its adoption in the United States is constantly and more frequently recently being advocated as a panacea for the alleged abuses of the present patent monopolies.

Bare mention of the many considerations pro and con and of the many speculative aspects of compulsory licensing would make a discussion of intolerable length. This discussion does not purport therefore to deal with anything like all the arguments which deserve consideration, nor does it deal fully with arguments on which it does touch. My purpose is merely to bring to the readers' attention some of the more important features of compulsory licensing in an attempt to show that any proposed amendment to the present Patent Law providing for compulsory licensing to remedy alleged abuses is without foundation and can be of no aid to the inventor, manufacturer or to the encouragement of the establishment of new industries and sufficiently increase employment to justify its adoption.

Let us examine first this argument that there is deliberate or improper shelving of patents, as this premise has often been furnished as one of the strongest reasons for urging the adoption of a complsory license system. Many people have made this assertion, but nobody has backed it up with any degree of persuasiveness, even less by proof, nor is there anything in print anywhere that I have seen, which indicates that this alleged suppression is a matter of the slightest consequence. This has been shown time and time again in every report of Congressional Committees relating to proposed changes in the Patent Law since 1912, and more particularly on the most recently proposed McFarlane Bill.

The late Mr. Thomas A. Edison testifying on this subject stated:

> "I have heard and read numerous statements that many corporations buy valuable inventions to suppress them, but no one cites specific cases. I myself do not know of a single case. There may be cases where a firm or a corporation has brought up an invention, introduced it, and afterwards bought up an improvement and ceased using the first patent—suppressed it, in fact. Why should that not be done? It is for the benefit of the public that it should get the latest improvement. I cannot see why the public should be asked to change the patent law to enable a competitor to get hold of the disused patent so he could have a basis on which to enter into competition with the pioneer of the invention who has introduced an improved machine.
>
> "Before any changes in the law are made, let the objectors cite instances where injustice has been worked on the public by the alleged suppression of patents for other reasons than those which were due to improvements."

It is heard that many inventors say that their inventions have been suppressed or "pigeonholed" and it is quite possible that many inventions have not been used by the manufacturer to whom they have been transferred, but it is more than likely that these inventions had not the slightest value, otherwise it is difficult to conceive that the manufacturer would willingly give up the profit which he might derive from the working of the invention on a commercial scale. It is probably true that many valuable patented inventions are not worked shortly after the issue of the patent, but this is more often due to the fact that the patent has issued so far in advance of the commercial development in the particular field that it cannot be worked with any degree of success until several years after the patent has issued. One illustration of this is found in the field of television in which many patents have been issued for several years and it is only very recently that any progress has been made to place television before the public on a commercial scale.

Furthermore, a long period of time almost invariably is required to develop and introduce an invention after it has been patented. One illustration on this point is the story of the Curtis Steam Turbine. The patent on the turbine was taken out in 1896. The General Electric Company acquired the rights of this patent and only after spending 7 or 8 years and millions of dollars was the turbine developed into commercial shape to begin getting any returns.

It seems obvious that the enforced working of a patent within a limited term under Compulsory License System would certainly work hardships on both inventor and manufacturer in these circumstances and prove a definite hindrance to the development of worthwhile inventions and industry in general.

In some cases the patentee, himself, because of poverty, cannot work the invention, and cannot get capital to enable him to work the invention. In such a situation he certainly will not refuse to give a license to someone else to work the invention. As a matter of fact, if it is commercially marketable, he will seek to sell the invention, or at least to license it. Most important, however, is the fact that industry, itself, will seek him out and a license can be granted and will be granted without any necessity of an enforceable license system.

While negotiating for a voluntary license or for the investment of capital to enable him to manufacture him-

self, the inventor is unable to work his invention. Under a Compulsory License System he would probably risk forfeiture of the invention for non-working within a specified time, or would be forced to grant a license under terms which often prove less favorable than under a voluntary license as experience abroad has shown. Is this in favor of a Compulsory License System?

Many believe the public is losing the benefit of thousands of patents because they have been purchased by a few trusts for the purpose of suppressing or shelving them, and avoiding the expense of making the improvements that use would compel. The fact is that competition takes care of such a situation when it exists, except in the very rare cases where there is no competition.

The reason why suppression of patents practically never occurs is obvious; the self interest of patent owners always lies in the direction of using any invention that really accomplishes its purpose more satisfactorily than the existing art.

Many proponents of the Compulsory License System in the United States have sought to support their proposals of Compulsory Licenses by foreign examples, as practically all of the industrially advanced foreign countries have provisions in their existing Patent Laws for the liberalization so-called of the manufacture, sale and use of all patented articles by one form or other of Compulsory License System.

If, therefore, there has been such a widespread suppression of patents as alleged, it is obvious that there would be some evidence in the industrial development in foreign states, and such evidence of the truth of this notion would be shown by a great number of applications for Compulsory Licenses having been filed in these foreign states. However, evidence and general opinion show that compulsory licensing has not been productive of worthwhile results abroad and indeed it has become pretty much of a dead letter in, at least, some of the most important countries. As to this, we need only to look to England to find applications for the grant of Compulsory Licenses are far from numerous. According to the official reports of the British Patent Comptroller to Parliament, in the nine year period from 1929 to 1937 only 31 applications were filed. as a result of which only 4 licenses were granted. Such results are made infinitesimally small when compared with the large number of patents existing in England. This same situation is true for practically every other country having a Compulsory License System.

For instance, Canada, which is the geographical neighbor of the United States and whose patent system is closely allied with that in the United States has had only 16 applications filed for Compulsory Licenses during the last 10 years, of which only 5 have been granted.

In Holland, during the same period, only 14 applications have been filed, of which only 5 have been granted.

In Switzerland, compulsory license provisions have been in the patent law since 1924 but, as yet, no applications have been filed.

Germany has perhaps had the most applications for compulsory licenses filed, of these many were results of the industrial chaos after the great war, but during the years 1927 to 1936—112 applications have been filed, and while no specific data is available as to the number of applications granted, it is extremely few, probably less than 20.

In Norway, the compulsory license system has been in force since 1910, the first plea for compulsory license was filed in August 1931, and the last plea was filed in October 1935. During this period of 4 years altogether twenty-five pleas were filed regarding forty-eight patents, of which practically all were radio patents which had been filed in Norway shortly after the war. Most of these pleas were granted as in these particular circumstances the opinion was that it would do the patentee no harm if compulsory licenses were granted.

It is interesting to note that in most cases this granting of compulsory licenses has no practical influence at all. The remarks of eminent patent attorneys in these countries, which have compulsory license systems, substantiate my opinion that while in practically every case the compulsory license provisions in these foreign states appear marvelous in theory, they have proved to be of very little practical importance, and in fact, in practice have proved to be of little direct value to industry. Certainly nothing in the example of foreign nations indicates that any advantage would be obtained by incorporating into the American Patent Law a provision for compulsory licenses.

It is an interesting note that the reasons for the proposal for the grant of Compulsory License in this country are to the greater extent punitive, i.e., to punish the manufacturer for not manufacturing his patented article, whereas, of course, history of the development of the Compulsory License System in the foreign countries shows that it is not so much a punitive as a protective measure to protect industry against the inroads of foreign commerce. Thus in England we find that a Compulsory License System has been enforced there since 1905, and it is still in the Law but at the time of its adoption in England, we must remember that England was a free trade country and its peak in industrial development with relation to certain other countries has passed. Both Germany and the United States had developed further in certain industries than Great Britain, particularly in connection with labor saving devices. Because of the free trade principle there was nothing to prevent articles manufactured in Germany and the United States, and protected by British patents, from being dumped in England to the detriment of the British industry, itself. Therefore, the purpose of the license legislation in England was to compel foreign owners of British patents to manufacture, or cause to be manufactured, the patented articles in Great Britain rather than to manufacture them abroad and import them into Great Britain, the theory being that this would result in the employment of British labor and British materials. This theory appears rather sound, but in practice it is seen from the above mentioned data that the provisions of the Law have had little, if any, effect in accomplishing the purpose for which it was designed, particularly as England has abandoned its free trade principle by erecting tariff barriers, which have the same effect of protecting British industry. There is no counter-part in the United States as, of course, the free trade principle has not been adopted and the tariff barriers are designed to protect American manufacturers. Therefore, on this basis there

(*Continued on page* 230)

ANALYSIS OF STRAINS AND STRESS IN GLASS

III—MEASURING INSTRUMENTS AND STRESS SYSTEMS

By A. J. MONACK* and E. E. BEETON
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The third article of this series describes the construction and use of the graduated quartz wedge, the Babinet compensator, and a polarimeter for extreme accuracy. It also discusses the analysis of single and combined stress systems in glass.—The Editor.

The ordinary quartz wedge is a wedge-shaped plate of quartz, cut so that its vertical axis is parallel with the glass plates between which it is mounted. In view of what has been explained previously it can be seen that the retardation of polarized light at any point on the wedge will be directly proportional to the thickness of the wedge at that point. Hence, as we move along the wedge toward the thick end the colors seen will be those of Table I, repeated herewith for convenience. The wedge should, of course, make an angle of 45 deg., with the vibration planes of the nicols in order to get colors of maximum sharpness.

TABLE I

PHASE DIFFERENCE AND COLOR WITH WHITE LIGHT

Phase Difference	*Color*
50 mμ	Iron gray
200	Grayish white
300	Yellow
425	Orange
530	Red
565	Violet
640	Blue
740	Green
840	Yellowish green
880	Yellow
945	Orange
1030	Red
1100	Violet
1200	Bluish green
1300	Green
1425	Yellow
1500	Orange

(The colors become paler as the phase difference increases)

The wedge is like all anisotropic materials in that one of the two rays travels faster in one direction than the other, and an arrow usually marks the direction of vibration of the slow ray in a quartz wedge. If the slow ray in a mineral section or a piece of strained glass, placed between the wedge and the polarizer at an angle of 45 deg. to the vibration planes of the nicols, is parallel with the slow ray in the wedge, the colors will rise—that is, they will follow the order in Table I when reading from top to bottom. If, on the other hand, the slow ray in the strained glass is at right angles to the slow ray in the wedge, the colors will fall, that is, follow the order in Table I when reading from bottom to top. To make the colors rise in this latter case, it is necessary to rotate the wedge, or the sample, through 90 deg. in a plane parallel to the planes of the nicols.

The dark gray color at the top of Table I occurs only once, and it is thus possible to determine the order of the interference color in strained glass by determining its relation to the dark gray. The proper procedure is to insert the wedge until the color in the wedge is the same as that whose order is to be found. The wedge is now withdrawn slowly, listing the colors produced, until the dark gray is reached. If the colors rise on withdrawing the wedge, instead of falling, the wedge or sample is rotated through 90 degrees.

It is of interest to note the significance of the dark gray color, because the retardation of one ray caused by the strained glass is balanced by the acceleration of the same ray produced by the wedge when this gray color is obtained. If the glass and the wedge could be viewed separately between crossed nicols when in this position, they would be found to produce the same color.

Since the ordinary quartz wedge cannot be used for exact measurements of retardation, a combination wedge is used for this purpose. Fig. 19 shows the construction of such a wedge. The wedge-shaped portion is of quartz, cut as explained above for the ordinary wedge. The lower portion is a mineral plate, which need not be quartz but is of such thickness that its retardation is equal in magnitude, but opposite in sign, to the retardation of the wedge at the line marked zero. The combination is cemented between glass plates for protection. When polarized light is passed through this combination wedge, a black line will appear at the zero point on the scale and colors will rise (see Table I) in both directions from this line. Then, if a plate of strained glass is placed between the wedge and the polarizer, the black line will be displaced a distance corresponding to the retardation caused by the glass, and this value can be

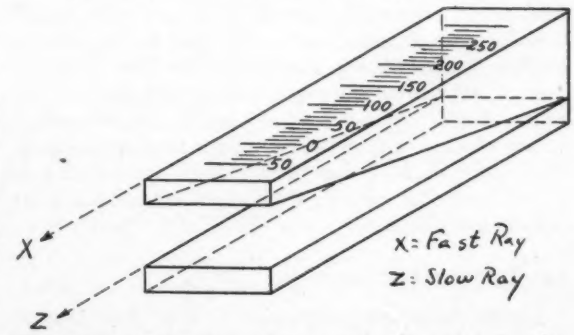


Fig. 19. Combination wedge with wedge-shaped quartz section above and mineral plate below.

*Now with RCA Manufacturing Company, Harrison, N. J.

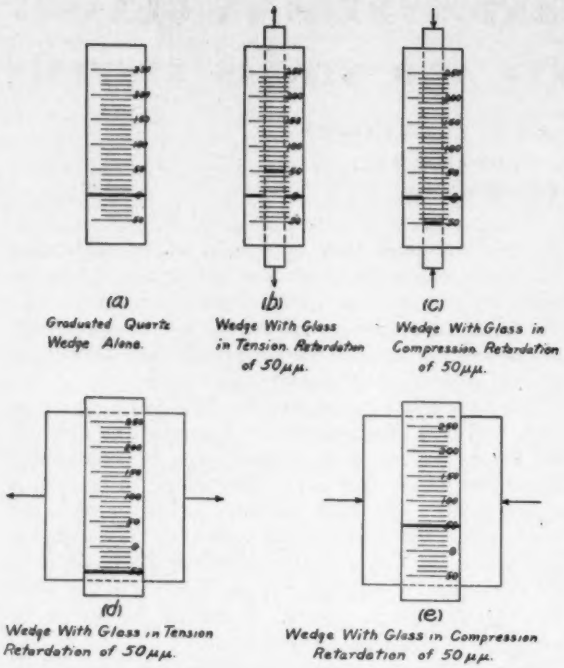

(a)
Graduated Quartz Wedge Alone.
(b)
Wedge With Glass in Tension. Retardation of 50 μμ.
(c)
Wedge With Glass in Compression. Retardation of 50 μμ.
(d)
Wedge With Glass in Tension Retardation of 50 μμ.
(e)
Wedge With Glass in Compression Retardation of 50 μμ.

Fig. 20. Appearance of graduated quartz wedge in polarized white light, with and without strained glass between wedge and polarizer.

read from the scale. The displacement of the black line occurs, of course, because at the line's new position the retardation of the wedge is exactly counterbalanced by that of the lower mineral plate plus that of the strained glass.

No colors appear when monochromatic light is used, but the wedge is then crossed by a series of black lines, one at the zero of the scale and the others at distances determined by the angle of the wedge. Except at the zero position, each black line marks the place where the faster of the two rays in the quartz has gained exactly one wave-length or a whole number of wave-lengths of the light used.

Fig. 20 shows the appearance of the wedge in polarized white light, both with and without strained glass between wedge and polarizer. The wedge alone is shown at (a); at (b) a strip of glass in tension has been interposed and the black line has moved upward; at (c), where the glass is in compression, the black line has moved downward. The glass in tension has been rotated 90 deg. at (d), and the line has now moved downward to indicate tension; and at (e) the glass in compression has been rotated 90 deg. and the line has been displaced upward. If the rules shown by these diagrams are forgotten, they can always be discovered by simply pulling a strip of glass with the hands and noting the displacement of the lines. Or the glass may be bent, of course, in which case tension will always be on the convex side, and compression on the concave side, of the specimen.

The Babinet Compensator

Fig. 21 shows the construction of a Babinet compensator, in which the lower wedge is fixed and the upper wedge moves over it when the knob is rotated. A dial shows the amount of rotation. The action of the compensator is similar in principle to that of the graduated quartz wedge and, with polarized white light, a black line will appear at the point where the thickness y in the upper wedge is equal to the thickness x in the lower. The reason for such appearance is the same as that given previously to explain the black line formed with the graduated wedge. At this point the direction of vibration of the slow ray in one wedge is at right angles to the direction of vibration of the slow ray in the other and, consequently, the black line occurs where the thicknesses of the wedges are equal. The position of the black line is marked on the wedge, and is shown as AB in Fig. 21.

The distance between the movable wedge and a reference point may be designated t_0 when x and y are equal, and this setting may correspond to zero on the dial. If a piece of strained glass is now introduced between the compensator and the polarizer, both compensator and direction of stress in the glass being, preferably, at 45 deg. with the vibration planes of analyzer and polarizer, the black line will no longer be at AB. The line will be displaced in one direction for tension in the glass, or in the opposite direction for compression, the direction of displacement depending upon the way in which the wedges have been arranged in the compensator.

Suppose, for instance, that the fixed wedge has its slow ray vibrating parallel to the length. Then the fast ray will vibrate parallel to the length in the movable wedge; and if a strip of glass in tension is inserted, the black line will be displaced to the right. This happens because at some point to the right the retardation of light in the glass plus the retardation of light in the lower wedge will be equal to the acceleration caused by the greater thickness of the upper wedge at that point. To bring the black line back to its original position AB requires a displacement of the upper wedge to the left, and the distance between the movable wedge and the reference will now be t.

For the displacement of the black line back to AB the acceleration of the upper wedge, caused by the thickness y, must be increased to counteract the retardation added to the lower wedge by the strained glass and the additional acceleration is supplied by the greater thickness of the upper wedge at any given point in the device when it is moved to the left. This is the same as saying that the

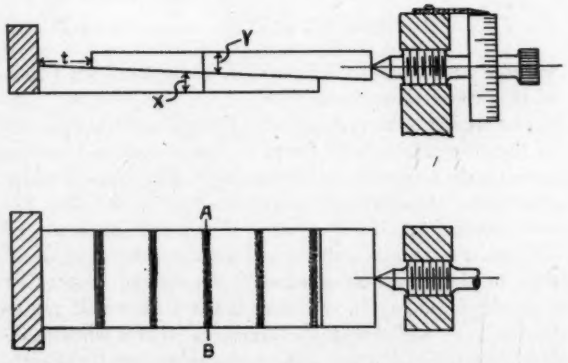


Fig. 21. Arrangement of wedges in the Babinet compensator.

retardation in the glass is proportional to the distance that the upper wedge has been moved, and in this case the upper wedge has been moved a distance equal to $(t—t_o)$. Then

$$R = k(t—t_o)$$

where k is a constant of the wedge.

Since t_o and t correspond to readings on the dial, it is not necessary to measure distances. But k must be determined if the dial is not calibrated directly in millimicrons, or some other unit of retardation, and if the manufacturer does not supply the value. The calibration may be done simply if a sensitive tint plate of known retardation is available or, in fact, any material of known retardation may be used. If these are not available, however, monochromatic light must be used.

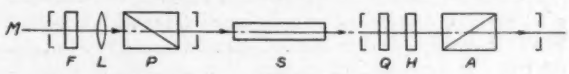
With polarized monochromatic light the pattern in the compensator differs from that obtained with polarized white light, since the compensator is now crossed by a series of black bands, each black line except the central one marking the place where the faster of the two rays has gained exactly one wave-length or a whole number of wave-lengths of the light used. A means for calibrating the compensator is thus provided, since reading the dial and then rotating it until the nearest dark line reaches AB and again taking a reading, the value of k can be calculated by dividing the wave-length of the light used by the difference of the two dial readings.

Extremely accurate measurements with the Babinet compensator are obtained only when monochromatic light is used. This is readily understandable since the value of k is determined in terms of a definite wave-length.

Polarimeter for Extreme Accuracy

It has been shown that retardation can be determined in several ways, that is, by the use of a tint plate, by the graduated quartz wedge, and by the Babinet compensator. For quantitative work the graduated quartz wedge offers a more accurate method than the estimation of color and eliminates the personal element to a great extent. The Babinet compensator is probably a little more precise than the graduated quartz wedge. But, for the sake of completeness a method due to Goranson and Adams[6] for a still more precise method is included. With the graduated quartz wedge or the Babinet compensator it is impossible to measure path-difference to a greater precision than about ± 5 mμ. With the method of Goranson and Adams, however, it is possible to measure path-difference to an accuracy of ± 0.05 mμ.

Fig. 22. Diagram showing arrangement of parts in an accurate polarimeter. Arrows show direction of light. M—Source of monochromatic light; F—Filter; L—Lens to render light parallel; P—Polarizer; S—Specimen; Q—Quarter-wave plate; H—Half shade device; A—Analyzer.

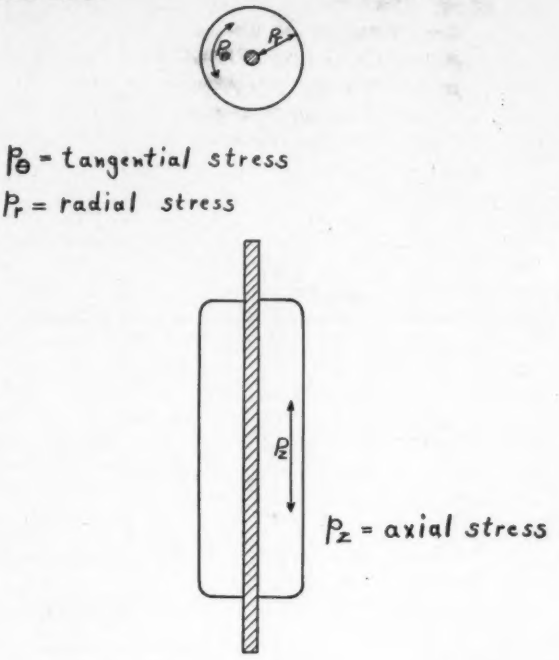


A brief description of the method will be of interest. Monochromatic light is rendered parallel and is then plane polarized and passed through the specimen under examination. The light then passes through a compensator plate that introduces a further retardation of exactly one-quarter of the wave-length of the light used, and finally through an analyzer. Fig. 22 gives a schematic diagram of such a polarimeter. Originally, the polarizer and analyzer are crossed, and the quarter-wave plate is arranged with one of its principal directions parallel to the vibration direction of the polarizer. The specimen is so oriented that one of its principal directions is at 45 deg. to the vibration direction of the polarizer, as is usual in any plane polariscope.

The plane polarized monochromatic light from the polarizer becomes elliptically polarized after passing through the specimen. The elliptically polarized light becomes plane polarized again after passing through the

[6]R. W. Goranson and L. H. Adams, *J. Franklin Inst.*, 216, 475-504 (1933).

Fig. 23. Stress directions in a glass-metal seal (beaded lead wire).



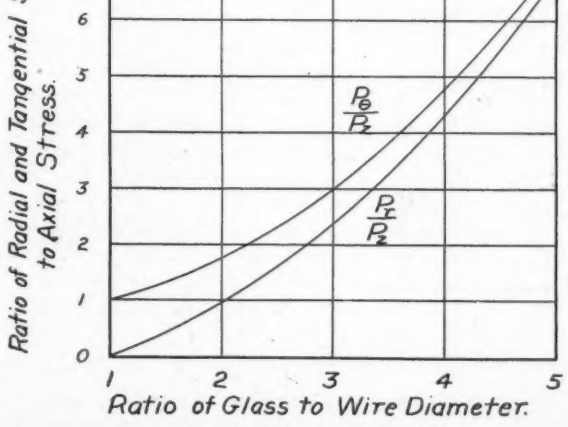


Fig. 24. Stress relations in a beaded lead.

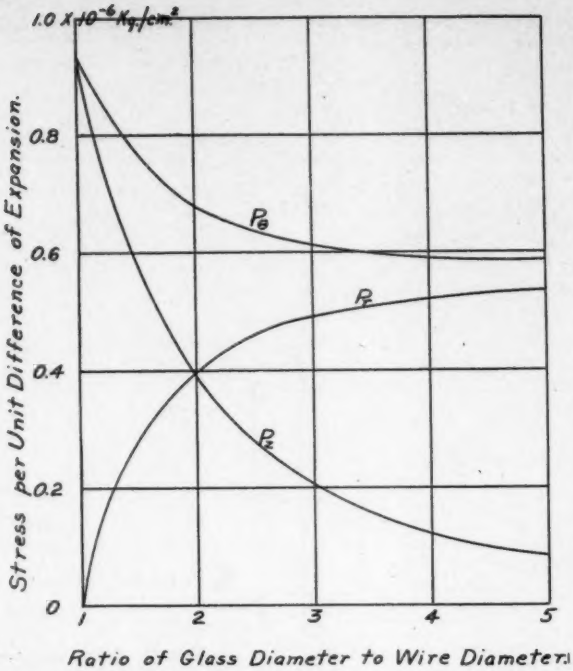


Fig. 25. Stresses in a beaded lead per unit difference of expansion.

quarter-wave plate, but it now vibrates in a different direction from that in which it vibrated after passing through the polarizer. By rotating the analyzer this plane polarized beam can be intercepted and the light extinguished. With this arrangement the amount of rotation of the analyzer is proportional to the retardation of the specimen. To determine when the light is exactly extinguished, a half-shade device, such as a Wright bi-quartz wedge[7], is inserted between the analyzer and the quarter-wave plate, giving a two-part field for a photometric match. Since only angular rotations of the analyzer are to be determined, very high accuracy can be attained. This method has not yet found extensive use but deserves consideration wherever extreme accuracy is necessary.

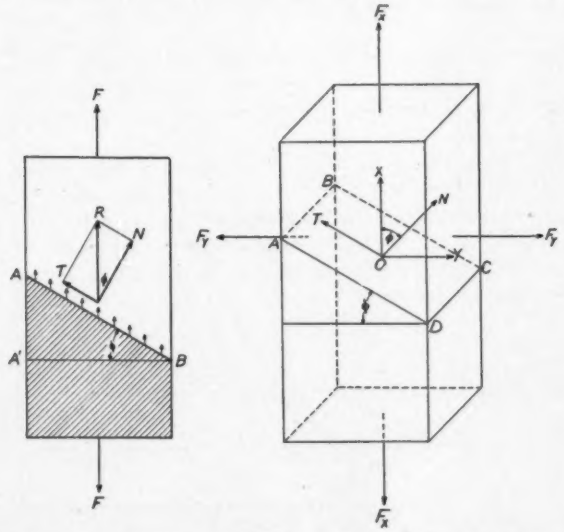


Fig. 26. Left—Forces in a thin bar of glass in tension.
Fig. 27. Right—Forces in a thin bar of glass subjected to tension in two directions.

Stress Systems That Reduce to a Single Stress

Stress systems can, for this discussion, be divided into three groups: (1) Stress in a single direction; (2) Stresses in three directions which reduce to stress in a single direction; (3) Combined stresses in two directions. A slab of glass in direct tension or compression is an example of the first case, and this has already been covered. Nearly all cases of strain, whether mechanical or thermal, fall into the second and third classes. The third group, while actually one of three-dimensional stress, is considered two-dimensional when the thickness of the specimen being studied is small in comparison with the length and width of the surface being examined in the polariscope. The second group is actually one of three-dimensional stress also, but, fortunately, such a stress system can be reduced to a stress in a single direction. A beaded wire lead, or glass-metal seal, is an example of the second group.

This case of the stresses in well-annealed glass beads around metallic wires, as shown by Figure 23, is particularly important in sealing lead wires into lamps and electronic devices. Hull and Burger[8] have made an extensive study of such seals. Poritsky[9] has analyzed this type of stress system mathematically and has shown that here the axial stress is the only one seen in a polariscope when the axis of the seal is at right angles to the light path. This is a fortunate circumstance, for it is comparatively easy to measure the axial stress along the wire by means of any of the methods already described, although an immersion-cell[10] should be used in order to obtain a correct measurement of retardation. Then by the use of a curve, such as in Fig. 24, the values of the radial and tangential stresses can be found.[11] Fig. 25 shows the theoretical values of the stresses for any glass and wire combination.[11] To use this curve it is necessary to know only the coefficients of expansion of the glass and the metal, and their diameters. The curves in both of these figures are constructed to give the values of the stress in the glass at the wire-glass interface, since this is the point at which the glass stresses reach a maximum. If the stresses at the interface are safe, it is certain that all the other stresses are likewise safe.

In a seal of this type it is important to know that the axial and tangential stresses always have the same sign, that is, both are either tension or compression, while the radial stress is always of opposite sign.

Combined Stress Systems

All stress systems previously discussed have consisted of stresses in one direction only, or systems which reduce to stress in a single direction. It is now necessary to take up systems composed of stresses in more than one direc-

[7]This wedge divides the field into two halves which are equally illuminated if no crystal is in the path of the light or if the crystal in the field is at extinction. The same applies to strained glass. If the crystal or strained glass is turned even a very small angle from extinction, the intensity of illumination in the two parts of the field is rendered unequal.
[8]A. W. Hull and E. E. Burger, *Physics*, **5**, 384-405 (1934).
[9]H. Poritsky, *Physics*, **5**, 405-411 (1934).
[10]E. E. Beeton, *Glass Industry*, **19**, 51-53 (1938).
[11]A. W. Hull and E. E. Burger, *Rev. Sci. Inst.*, **7**, 98 (1936).

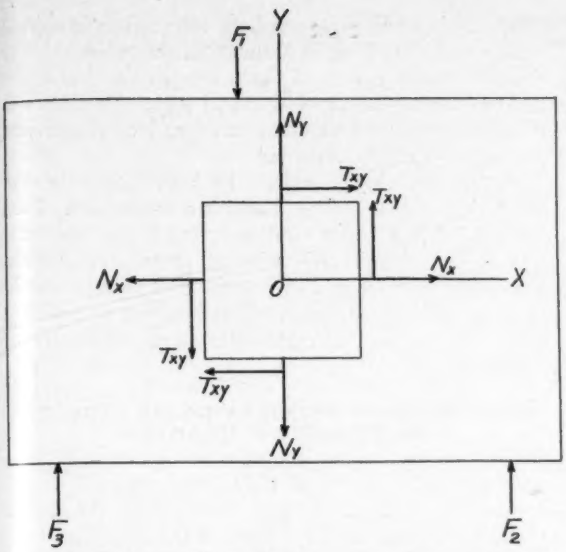


Fig. 28. Diagram illustrating the general case of plane stress.

tion, that is, a consideration of the general stress analysis, of which the two previous analyses were special cases. Although it is possible to make a complete stress analysis without such knowledge, it will be advisable to give a few fundamental points from the theory of elasticity of solids; and any such treatment leads to the concept of principal stresses.

Principal Stresses

Fig. 26 shows a thin bar of glass in tension. The force pulling the bar is *F*, and it is assumed that the lower shaded part is isolated from the upper. The vertical arrows drawn along AB represent the forces which the upper part exerts on the lower, and the sum of these forces must, of course, equal *F*. The unit stress over the cross-section AB is equal to *F* divided by the area of the section and this is shown as *R* in the diagram. *R* can be resolved into a component *N*, normal to the surface AB, and a component *T*, tangential to the surface. It can be shown that *N* is a maximum when the angle ϕ is 0 deg., where *N* is equal to *F* divided by the area of the section A′B; and a minimum when ϕ is 90 deg., were *N* equals zero. Also, *T* is a maximum when ϕ is 45 deg., where *T* is equal to the maximum *N* divided by 2; and a minimum when ϕ is 0 deg. and 90 deg., where *T* equals zero.

By a similar line of reasoning it can be shown that when a thin bar is subjected to two tensions at right angles, as shown in Fig. 27, the normal stresses acting upon a cross-sectional area, such as ABCD, reach a maximum or minimum value when ϕ equals 0 or 90 deg., and that the shearing stress in this section disappears. The maximum shear is reached when ϕ equals 45 degrees.

The directions where the normal stresses reach a maximum or minimum, while the shearing stress disappears, are called the *principal stress directions*, and the normal stresses are called *principal stresses*.

In Fig. 27 the principal stress directions coincide with the directions of the external forces applied to the bar, but the general case of plane stress can be discussed now in connection with Fig. 28. F_1, F_2, and F_3 are external forces. If the small element is imagined to be cut out and isolated, the normal stresses on each face of the element are shown by N_x and N_y, while the tangential stresses, equal on all faces, are marked T_{xy}. The axes of reference are as shown. The plane stresses in a thin element are completely defined in this way with reference to the external forces.

Should the element now be rotated through an angle ϕ with respect to the reference axes, as shown in Fig. 29, the shearing stresses will become zero at one value of ϕ. The stresses P and Q now completely define the stress system of the element. P and Q are the principal stresses, and the principal stress directions are ϕ and $\phi+90$ deg., with respect to the reference axes. The stress measured at any point in the glass is equal to P —Q. It is further characteristic of such stresses that one is always a maximum and the other is a minimum, so if the element is rotated 45 deg. with respect to the principal stress directions, that is, $\phi + 45$ deg. with respect to the original reference axes, the shearing stress becomes a maximum and equal to

$$\frac{P - Q}{2}$$

With principal stresses and principal stress directions defined, it is now possible to consider the photoelastic determination of stress magnitudes and distributions, and any such determination must be expressed in terms of the principal stresses and principal stress directions. Knowledge of the magnitude and direction of the principal stresses at every point in the body furnishes a complete solution of the stress problem. Both the normal and shearing stresses in any other direction can be derived by means of simple equations.

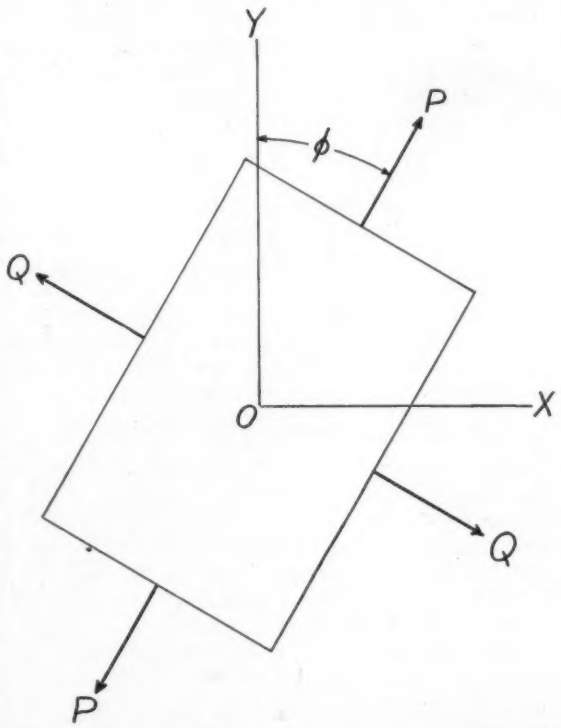


Fig. 29. Diagram showing principal stress directions.

Principal Stresses and Retardation

It was stated earlier that the retardation at any point in a glass specimen, subjected to simple tension or compression in one direction, was given by the equation $R = Cds$, where R is the retardation, C the photoelastic constant of the glass, d the thickness through which the light travels, and s the unit stress. In connection with combined stresses it has just been demonstrated that at any point in the glass the stress is equal to the difference of the principal stresses at that point, that is, P — Q. The general stress equation must then be rewritten to take this new development into account, and becomes

$$R = C\ (P - Q)\ d,$$

where (P — Q) replaces s.

Summary of Stresses and Retardations

It is well, at this point, to summarize the previous developments on stress, stress directions, and retardations.

1. At every point in glass under plane stress there are two directions at which the shearing stresses vanish and only normal stresses are present. These normal stresses are called principal stresses, and their directions are called directions of principal stress. Furthermore, during rotation about the point considered, one of these principal stresses reaches a maximum value and the other reaches a minimum value, when the angle of rotation is such that shearing stresses vanish. The maximum stress is called P and the minimum stress is called Q. The directions of these stresses make an angle of 90 deg. with each other, and angles of ϕ and $\phi + 90$ with the original axes of reference, X and Y.

2. The retardation at any point is given by the relation

$$R = C\ (P - Q)\ d.$$

3. In the case of simple tension or compression in a single direction, the direction of stress coincides with the direction of the applied force. The stress is a principal stress, the other principal stress being absent. Hence, the retardation is given by the equation

$$R = C\ d\ s,$$

where s is equivalent to P in the previous equation and Q is equal to zero.

4. At any point the shearing stresses have a value of zero in the directions of principal stress, and reach a maximum value of $\frac{P - Q}{2}$ at an angle of 45 deg. with the directions of principal stress.

(The final article in this series, to be published in the July issue, will discuss principal stresses and their evaluation.)

DALLAS BURRESS DIES SUDDENLY

Among his many friends and acquaintances throughout the glass manufacturing world, news of the death of Dallas D. Burress, Chief Chemist of the Ball Brothers Co., Muncie, Ind., has been received with distinct shock and has left a universal feeling of regret that such a promising career should be terminated so early. Mr. Burress died suddenly on May 2, 1939.

Born in Madison, Indiana, thirty-one years ago, Dallas Burress had been associated with the Ball Brothers Company for twelve years and had resided in Muncie during this period. Although young in years his achievements in the field of glass composition, batch handling and other batch house problems have attracted favorable attention and consideration throughout the industry. Particularly in the matter of batch segregation, his studies and conclusions are considered authoritative and his contributions to THE GLASS INDUSTRY and other technical journals are highly regarded.

Mr. Burress always evidenced a keen interest in manufacturing and control problems and the breadth of this interest led him into a continual search for "the better way to do things." His winning personality, coupled with wide knowledge and mature judgment, made his presence welcome at various glass conferences and meetings, where his helpful contributions and comments were highly valued.

IMPROVEMENT NOTED IN GLASS INDUSTRY DURING FIRST QUARTER

Activity in the United States glass industry increased during the first quarter of 1939 as compared to the corresponding period of last year, according to the Specialties Division, Bureau of Foreign and Domestic Commerce, Department of Commerce.

Higher production levels and larger domestic and export shipments were among the favorable factors noted. Plate glass output was three times as great as during the first three months of 1938, window glass production increased 50 per cent, and container shipments were larger by 13 per cent. These three branches account for 75 per cent of the output of the entire industry, it was said. Statistics for the more specialized lines such as illuminating and table glassware are not available but general improvement has been reported.

Decreased foreign competition traceable to unsettled conditions in Japan and Germany, which now includes former Czech glass plants, is expected to further stimulate foreign sales of American made wares. Exports of American glass products during the first quarter of 1939 were valued at $2,023,372; imports were valued at $1,237,401, according to the Department of Commerce.

BELGIAN GOVERNMENT AUTHORIZES CONTROL OF BLOWN GLASS PRODUCTION

The Belgian Government has authorized restriction in production of blown glassware in that country, according to a report received by the U. S. Department of Commerce from its Brussels Office. As a result, the voluntary agreement reached between members of the Belgian Glassware Association is enforced upon all producers, whether members of the association or not, in the blown glass industry.

One of the obligations voluntarily assumed by members of the Association was limitation of their production to the level as of August 1, 1937, or 69.64 per cent of their production capacity. Ordinary glass or half-crystal ware, finished or semi-finished, such as goblets, tumblers, wine glasses, carafes, jugs, cups, dishes, finger bowls, and similar articles are included among the types of blown glassware for which production will be restricted.

This interdiction against installation of supplementary equipment does not refer to new inventions or the use of new manufacturing processes, or to replacement of worn-out material, provided that the amount of glass worked up for the manufacture of blown glassware does not exceed that as of August 1, 1937, according to the report.

TABLEWARE GLASSES MELTED IN TANKS

• *The following article was translated from the French publication "Verre et Silicates Industriels," Vol. IX., No. 34, by Elsie A. Preston.—The Editor.*

A great number of glass objects (bottles, flasks, goblets, jam jars, various containers), are usually manufactured out of a soda-lime glass of very simple chemical composition; in fact the batch varies little from the following proportions:—

Sand	100 parts
Soda	38 parts
Limestone	20 parts

Sometimes a very small quantity of sulphate of soda is added, and nearly always a little arsenic.

However, new factors have arisen which have forced manufacturers to make changes in this state of affairs:—economic considerations, such as the desire to improve the thermal efficiency of the melting furnace, increasing its hourly production, which it has been possible to accomplish by the use of more fusible compositions. Certain factors of a technological nature, however, have had a more marked and more decisive influence, since they call for direct and radical measures: for instance, the necessity of supplying to the consumer a product answering to new requirements (greater chemical endurance or mechanical strength, etc.)

Such changes have taken place gradually in the habitual constituents of tableware glass, thanks to the scientific work carried out in research laboratories. In the last few years especially, the latter have successfully explored the difficult field of the chemistry of the silicates —alumina, boric acid, barium, to mention only a few substances. The new selling price is up a little, it is true, but on the other hand there have resulted advantages which have largely compensated for this increase; and anyway it is hardly noticeable on the selling price of the finished article.

The new glasses are a little less rich in silica than their predecessors, therefore having greater fusibility of the batch, which permits of obtaining more easily a homogeneous melt, free from cords or ream; in addition, there is less risk of devitrification (it is known that very silicious glasses are liable to throw out SiO_2 in the form of tridymite or cristobalite) and of contamination of the glass melt by scum. (The latter indeed contains a high proportion of silica, and is therefore favored by an abundance of this material in the mix.) A glass which is very rich in silica also presents other drawbacks: in certain cases there is difficulty in preventing the deformation of the pressed articles, during their transfer from the mould to the annealing oven: there is insufficient relief in the impressions (letters or designs): there is a tendency of the objects to become stuck together if they should be in contact with each other during the period in the annealing oven: there is difficulty in making pieces with sharp angles (rectangular bottles, for instance, of which the shoulders are often "clear," i.e. too thin).

In view of the fact that tableware glass is always high in alkali, it follows that if we are to increase its durability we cannot deal directly with the soda content, but must have recourse to various other ingredients set forth below.

Let us note first, that the sum of the alkaline-earth bases can be considered as very satisfactory when it lies between 8.25 and 8.5 per cent; there are, however, also some glasses of good quality of which the content in alkaline-earths varies more or less from the normal value indicated above; that is so, for instance, with certain lighting glasses of large dimensions, thermos flasks, lamp glasses, etc. It is, however, possible to readjust the chemical composition of these different varieties of glass so as to incorporate 8.25 per cent of alkaline-earth bases at the same time as the correcting elements intended to restore to them the physical qualities which are characteristic (viscosity, mechanical strength, etc.).

Amongst the first of the new materials usually introduced into the new batches we may mention feldspar, at the rate of 6-7 parts per 100 parts of sand; the alumina contributed thereby produces a very significant increase in the resistance of the glass to weathering, and particularly towards packing materials. Let us note in passing that the total alumina present in the glass is not due to feldspar alone, but that part of the element in question arises evidently from the wear of the walls of the melting furnace.

Certain containers intended to hold products which will be subjected to pasteurization are required to offer great resistance to variations of temperature; alumina is highly to be recommended for this also.

Boric acid added in small quantities (2-3 parts per 100 parts of sand), considerably improves the physical qualities of the glass (greater fusibility, lowering of the coefficient of expansion, etc.) and produces at the same time a more attractive lustre.

The addition of barium oxide to the composition (1 part of barium to 100 parts of sand) also favors the fusion of the batch, and the obtaining of a homogeneous melt.

It is to be noted, however, that the use of excessive quantities of one or another of these ingredients may entail serious disturbances in manufacture. Technical literature is full of miscellaneous publications dealing with the chemical and physical properties of glass as affected by its chemical composition. There, therefore, exists extensive literature to which it is advisable to refer before modifying the chemical composition of a type of glass, or undertaking the manufacture of a new type.

Finally we recall that certain glassmen make use of sodium sulphate as a refining agent. It goes without saying that highly fusible compositions have no need of refining agents, and by all the evidence there is room in the circumstances to decrease, very considerably, the proportions of products intended to facilitate refining, because they are becoming superfluous.

As for arsenic, it is known that this plays a part in stabilizing the color of the glass, especially in the case of water-white "flint," in the sense that it influences profoundly the reactions of the physico-chemical equilibrium governing the relative proportions of Fe_2O_3 and FeO present in the melt. Assuming that iron is always found

in very small quantities in water-white glass for tableware, the quantity of arsenic which it is advisable to use is about 1 part to 400 parts of sand. The use of larger quantities is not only a waste, but may also have an unfavorable repercussion on the color of the glass, which suddenly reappears, or rather becomes accentuated, when it was easily concealed before; this sudden coloration is the result of the disturbance of the balance of iron oxides, because here we are dealing with reversible reactions; the glassman is confronted anew by the problem of decolorizing, already so thankless by nature, and he can only solve it by groping, at considerable expense.

Finally, the use of cullet in large proportions does not offer any real advantages; the apparent benefit of the very low price of this product does not compensate for the additional expense involved through the necessity of raising the normal operating temperature of the tank and refining chamber.

It goes without saying that the above considerations apply equally to the colored glasses manufactured into tableware. In brief, the simultaneous addition of alumina, boric acid and barium to the batch, while on the one hand it entails additional expense, permits on the other hand increasing the capacity of the melting furnace, favors the obtaining of a homogeneous melt, and improves or stabilizes the physical properties of the glass in course of molding, and therefore of the final product.

COMPULSORY LICENSING OF PATENTS

(*Continued from page* 222)

is no reason for the belief that it would be of any material assistance to American industry to adopt a system for the compulsory licensing of patents. Moreover, revisions of the International Convention for the Protection of Industrial Property and foreign patent laws have had one purpose; to liberalize and render the working provisions less onerous to patentees indicating, in my view, that harsh and restrictive measures have failed.

It may be true, as some point out, that while the Compulsory License System is of no direct benefit to industry, the mere existence of Compulsory License provisions would have an indirect influence by inducing the holders of patents to grant voluntary licenses, or to work the patent themselves rather than run the risk of applications being made to the Commissioner for a Compulsory License. Whether or not this is true is purely a matter of guesswork, as there is no possible way of ascertaining the reasons for the licensing of patents. It is my view, however, that if a patent is valuable, the patent owner would put the invention into operation, or would grant a license to an interested party purely for selfish reasons even if the Compulsory License System did not exist.

Mention also should be made that under the provisions of a Compulsory License System, it would often be necessary for the Commissioner (or other designated authority) to determine the royalties to be paid under the license, but not only is it obvious that this would be a terrific burden on the Patent Office in the hearing of such applications, but it would be practically impossible for a Commissioner or Court to determine what a reasonable or an equitable royalty would be under the compulsory license of a patent. Furthermore, the provision for compelling a license attaches to every patent the liability of defending such a proceeding, and imposes upon the patent owner the burden of defending such a proceeding, as it would be necessary to have a full showing of the facts by both sides as a basis for a judgment as to what terms and conditions would be fair under the license. This burden of litigation would certainly be to the detriment of the small inventor or patent owner.

No country has benefited more by its patent system than the United States as will be seen by comparing the tremendous industrial development of the United States to that of other counries, even to those which have what are considered to be liberal patent laws, as Germany and England. It is generally conceded that this advanced industrial development in the United States is attributed to its liberal patent law and there does not seem to be any good reason to impose upon this system that has worked so well, a system that has been shown in other countries to have worked to such little advantage. The patent system itself is sound and while there may be, and in fact are, defects in its practice, such defects may be overcome by a change in practice under the laws. There is, however, an overwhelming argument against altering the system by the adoption of a Compulsory License System.

DETERMINATION OF BORON IN SPECIAL GLASSES

The method for determining boric oxide in glass, described in J. Research NBS 16, 421 (1936) RP882, is not applicable to glasses containing more than small amounts of barium, iron and zinc, and lead. Since the publication of that method, F. W. Glaze and A. N. Finn have found that the substitution of sulfuric acid for hydrochloric acid overcomes the interference of those elements.

When sulfuric acid is used, the partition coefficient, K, becomes $0.417—0.00232t$ if the temperature (t) is between 20° and 30°C. For hydrochloric acid, $K=0.668—0.0469\sqrt{t}$. That sulfuric acid can be used satisfactorily is indicated by the fact that 32 determinations were made of boric oxide in glasses and synthetic mixtures containing different amounts of barium, zinc, iron, lead, and boron with an average difference of ± 0.06 per cent between the percentage of boron present and that found.

The substitution of sulfuric for hydrochloric acid involves no change in the reported analytical procedure, except that the concentrated hydrochloric acid (sp gr 1.18) and the 1:1 acid must be replaced by 32 per cent and 16 per cent (by volume) sulfuric acid, respectively. Computation of the amount of boron present must be based on the partition coefficient in sulfuric acid solution, $K=0.417—0.00232t$.

Although the use of hydrochloric acid will be satisfactory in determining boron in most commercial glasses, there are many special glasses, including the large variety of optical glasses, which contain large amounts of lead, barium, and zinc. To determine boron in these glasses, one should use the sulfuric acid modification of the procedure originally reported.—*Technical News Bulletin, National Bureau of Standards, May*, 1939.

• The Latchford Glass Co., Los Angeles, California, has changed its name to the Latchford-Marble Glass Co.

DECOLORIZATION OF MANGANESE AND SULFUR IN GLASS WITH APPLICATION TO USE OF FURNACE SLAGS

By A. E. BADGER*

ABSTRACT—The purple color of glasses caused by trivalent manganese may be prevented by adding zinc sulfide or cadmium sulfide to the glass batch. Excess of zinc sulfide produces amber colors, while excess cadmium sulfide causes a canary-yellow color. The use of slags in glass batches usually produces amber or black glasses due to the sulfur, manganese, and iron contained in the slag. The color due to sulfur and manganese may be prevented by adding zinc oxide to the glass batch. For the slag used in these experiments, about one part of zinc oxide is necessary to decolorize one part of slag, the color of the glass being greenish due to the iron content. The amber color caused by introducing 5 per cent of slag in a glass batch may be prevented also by the use of arsenic or antimony oxides, which act as high-temperatures oxidizers of the sulfur in the slag.

Introduction

When glasses containing manganese are melted under oxidizing conditions, a purple color due to trivalent manganese is produced. This appears black if enough manganese is present. If the glass is melted under reducing conditions, the manganese is in the divalent form and the glass is practically colorless. This reduction of manganese may be effected by contact with furnace gases or by means of a reducing agent mixed in with the glass batch.

The following experiments were made on a small scale. Application of results to commercial practice should be made with caution since conditions of time, temperature, and furnace atmosphere would be altered markedly.

Use of Zinc or Cadmium Sulfide as a Reducing Agent for Manganese in Glasses

The decolorization of manganese in glasses may be made by means of various reducing agents in the batch. The following experiments utilized zinc sulfide or cadmium sulfide as a reducing agent. In the use of the former the following reaction would be expected, namely, $3\,Mn_2O_3 + ZnS = 6\,MnO + ZnO + SO_2$, the weights of Mn_2O_3 and ZnS being in the proportion of about 5 to 1. The reduction in valence of the manganese would produce a nearly colorless glass from the original purple.

In order to study this effect, a series of borax glasses containing 0.5 per cent MnO_2 (equivalent to 0.44 per cent cent Mn_2O_3 in the glass) with additions of zinc sulfide varying up to 2 per cent ZnS was melted in platinum crucibles. It was found that the glass batch containing 0.5 per cent MnO_2 was nearly black and that this glass could be decolorized by the addition to the batch of .075 per cent ZnS. A similar decolorizing action was possessed by cadmium sulfide. Glasses containing more than .075 per cent ZnS tended towards amber colors, while that with 2 per cent ZnS was opaque due to the large excess of this material. The weights of Mn_2O_3 and ZnS in the colorless glass were in the proportion of 0.44 to .075 or about 6 to 1, which is satisfactory agreement with the predicted ratio of 5 to 1.

The action of zinc sulfide as a decolorizer for manganese, which was shown in the melts of borax glasses,

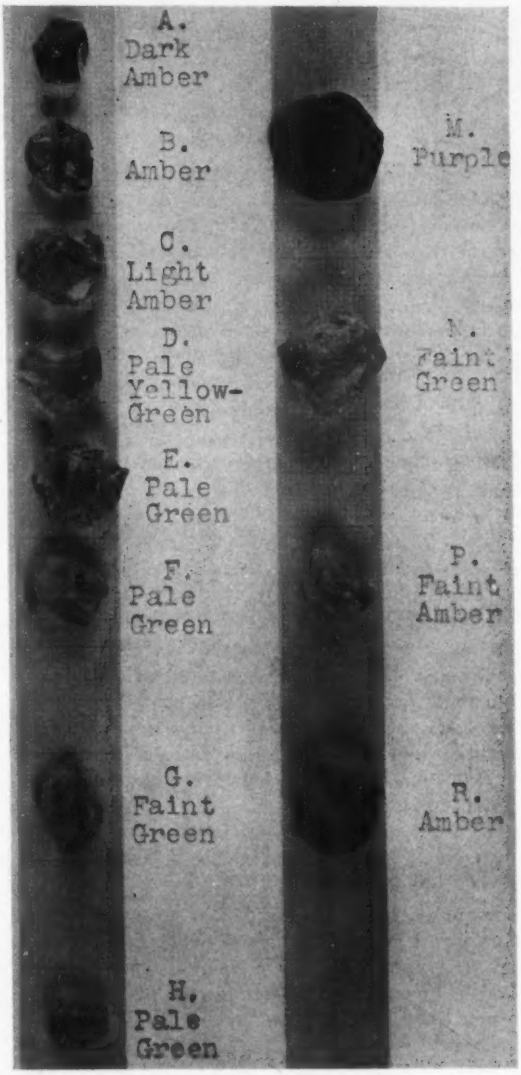


Fig. 1. Series A to F shows the effect of additions of zinc oxide to an amber glass containing 5% slag.

Glass A is made without additions of ZnO and is amber in color.

Glasses B to F contain 1 to 5% ZnO, respectively, and a progressive lightening in color is produced.

Glass G shows the decolorizing action of 0.4% arsenic oxide when added to Glass A, while Glass H shows the similar effect of antimony oxide.

Series M, N, P, and R shows the effect of adding ZnS in the amounts of 0.05%, 0.25%, 1.0%, and 4.0%, respectively, to a purple glass containing 0.5% MnO_2. Small additions decolorize the purple color, while larger amounts form amber glasses.

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1. The sample of slag and its chemical analysis were made available through the courtesy of Mr. Fred Hubbard, Standard Slag Co., Youngstown, Ohio.

was checked in a soda-lime-silica glass of the composition 72 per cent SiO_2, 12 per cent CaO, 16 per cent Na_2O, to which 0.5 per cent MnO_2 was added. Meltings were made in small porcelain crucibles. The batch consisted of sand, calcium carbonate, soda, and manganese dioxide. To this batch the following various amounts of zinc sulfide or of cadmium sulfide were added, the colors of the resulting glasses being noted also:

.05% ZnS (amethyst glass)
.10% ZnS (amethyst glass)
.25% ZnS (colorless glass)
.50% ZnS (colorless glass)
1.00% ZnS (very faint amber glass)
2.00% ZnS (light amber)
4.00% ZnS (light amber)
0.5 % CdS (colorless glass)
1.0 % CdS (very faint yellow)
2.0 % CdS (canary yellow)

These results show that the purple color produced by the addition of 0.5 per cent MnO_2 was decolorized by the use of from 0.25 to 0.50 per cent of zinc sulfide (see Fig. 1, Glasses M, N, P, R), the sulfide of cadmium acting similarly. This amount of ZnS necessary to decolorize these soda-lime-silica glasses is greater than that in the borax glasses since the silicate melts were held at a high temperature and some ZnS was lost by oxidation. The addition of 2 per cent of ZnS or of CdS formed pleasing amber or canary yellow colors, respectively.

Larger amounts of manganese can be reduced to form nearly colorless glasses by using greater quantities of zinc sulfide. In one series of tests, a glass batch containing 6 per cent of MnO_2 was decolorized by the use of 3 per cent ZnS.

Slag as a Raw Material for Glass-making

The utilization of furnace slags in glass batches is advantageous due to the low cost of this material. The relatively large quantities of sulfur, manganese, and iron which such slags usually contain restrict its use to the production of colored ware or, for colorless "flints," to such small amounts in the batch that only a faint color is produced.

Effect of Zinc Oxide on Color of Glasses made from Batches containing Slag

For preliminary tests on the color produced by slag in glass batches, a series of glasses consisting of 5 parts borax + 1 part slag + 1 part of various materials was melted in platinum crucibles and cast on an iron plate. The powdered slag[1] used for these tests had the following chemical composition:

35.63% SiO_2
12.14% Al_2O_3
2.79% MgO
46.42% CaO
1.77% S
1.47% MnO
0.29% Fe_2O_3

The various additions which were made consisted of 1 part of each of the following materials, namely $NaNO_3$, ZnO, BaO, CaO, V_2O_5, CeO_2, PbO, Ni_2O_3, CdO, MgO, SrO, TiO_2, and ZrO_2. The glasses resulting from the fusions were black with the following exceptions: the glass containing $NaNO_3$ was brown; the glass with CdO was yellow opaque; the glass with ZnO was water clear.

Since the effect of zinc oxide on decolorizing the glass was so pronounced, some additional experiments were made using this oxide in smaller quantities than the amount of 14 per cent which was used previously. This series consisted of melts of 5 parts borax + 1 part slag with additions of 0.02, 0.05, 0.12, 0.25, and 0.50 part of ZnO, respectively. The smallest addition was found to produce a brown glass; the second and third amounts produced opaque glasses; 0.25 part of ZnO resulted in a clear light yellow glass, while 0.50 part produced a glass with only a faint yellow color. It may be concluded that, for the decolorization of 1 part of slag, between 0.5 and 1 part of ZnO is necessary.

The production of opaque glasses by the addition of 0.05 or 0.12 part of ZnO may be explained on the assumption that these amounts of ZnO (1.6 and 4 per cent, respectively) react with the sulfur in the slag to form an excess of zinc sulfide. This material forms an opaque glass just as was found in the melt containing 2 per cent ZnS described in Section II. Further increase in the ZnO content forms a clear glass, that is, the precipitate of ZnS dissolves. This assumption was proved by adding 2 per cent ZnS to a borax glass to form an opaque glass and then adding ZnO to this fusion, whereupon the precipitate dissolved.

The above experiences with borax glasses were applied to melts of soda-lime-silica glasses of a commercial type with the results described in the following account. A batch consisting of 61.1 parts sand, 25 parts slag, and 23.8 parts sodium carbonate forms a glass of the composition 70.0 per cent SiO_2, 3.1 per cent Al_2O_3, 0.7 per cent MgO, 11.6 per cent CaO, 0.37 per cent MnO (or equivalent Mn_2O_3), 0.44 per cent S, 13.9 per cent Na_2O. This glass was found to be black. Additions of ZnO were made to this batch in the amounts of ½, 1, 2, and 4 per cent respectively, and a progressive lightening in shade was produced. However, even 4 per cent addition of ZnO produced a deep amber glass.

The substitution of soda niter for part of the soda ash in the batch should aid in removing part of the sulfur by oxidation. This effect was studied by using the glass batch, 61.1 parts sand, 25 parts slag, 17.1 parts sodium carbonate, and 10.7 parts sodium nitrate, the melted composition (neglecting sulfur) being the same as the above. Additions of ZnO were made in the same amounts as stated above and the colors of the melted glasses compared with those produced by the all-carbonate batch. The results showed that the batches containing niter were somewhat lighter in shade. However, all the glasses were amber or black.

Since the amount of zinc oxide used in commercial glass batches must be small due to economic considerations, a series of glasses containing 1 per cent ZnO was made. Batches containing niter were tried and also niter-free batches. To these batches additions of a slag were made in amounts from 5 to 25 per cent. The colors varied from amber to nearly black.

In order to determine the least amount of zinc oxide necessary to decolorize a fixed amount of slag in a glass batch, a series of melts were made using the following soda-lime-silica batch, namely, 70.7 parts sand, 10.0

parts slag, 23.8 parts Na_2CO_3, 9.6 parts $CaCO_3$. Various amounts of zinc oxide were added to this batch, producing the colored glasses shown in Table I.

TABLE I

Amount ZnO added to batch	*Color of Glass*
0	Dark amber
1	Amber
2	Light amber
4	Light amber
6	Light amber
8	Pale yellow-green
12	Pale green

The results given in Table I indicate that from 8 to 12 parts of ZnO are necessary to decolorize 10 parts of slag, or roughly 1 part of ZnO for each part of slag.

Effect of Additions of Arsenic or Antimony Oxides on Color of Glasses made from Batches containing Slag

The amount of zinc oxide necessary to neutralize the color caused by the addition of slag might be decreased if part of the sulfur in the slag were removed by some means. In order to oxidize part of the sulfur in the glass batch, it is advisable to add some material such as the oxide of arsenic, antimony, or cerium, which will liberate oxygen at a high temperature. For an experimental test of these effects, a soda-lime-silica batch was melted with various additions of As_2O_3 and ZnO. The batches used and the colors produced are listed in Table II.

TABLE II

Sand	Slag	Na_2CO_3	$NaNO_3$	As_2O_3	ZnO	Color of Glass
61.1	25.0	18.8	8.0	0	0	Dark amber
"	"	"	"	0.3	0	Amber
"	"	"	"	0.6	0	"
"	"	"	"	0.9	0	Light amber
"	"	"	"	0	3	" "
"	"	"	"	0.3	3	" "
"	"	"	"	0.6	3	" "
"	"	"	"	0.9	3	" "
"	"	"	"	0	6	" "
"	"	"	"	0.3	6	" "
"	"	"	"	0.6	6	" "
"	"	"	"	0.9	6	Pale yellow-green

TABLE III

Sand	Slag	Na_2CO_3	$NaNO_3$	$CaCO_3$	As_2O_3	ZnO	Sb_2O_3	Color
71.1	5.0	18.8	8.0	17.9	0	0	0	Dark amber
"	"	"	"	"	"	1	"	Amber
"	"	"	"	"	"	2	"	Light amber
"	"	"	"	"	"	3	"	Pale yellow-green
"	"	"	"	"	"	4	"	Pale green
"	"	"	"	"	"	5	"	"
"	"	"	"	"	0.4	0	"	Faint green
"	"	"	"	"	"	1	"	" "
"	"	"	"	"	"	2	"	" "
"	"	"	"	"	"	3	"	" "
"	"	"	"	"	"	4	"	" "
"	"	"	"	"	"	5	"	" "
"	"	"	"	"	0	0	0.4	Pale yellow-green
"	"	"	"	"	"	1	"	" "
"	"	"	"	"	"	2	"	Pale green
"	"	"	"	"	"	3	"	" "
"	"	"	"	"	"	4	"	" "
"	"	"	"	"	"	5	"	" "

The results given in Table II show that arsenic oxide tends to lighten the amber color. They also confirm the decolorizing action of ZnO. However, the amount of slag used was too great to be decolorized by the quantities of arsenic and zinc which were used. Therefore, a small series of melts was made in which the slag was decreased to ⅕ that shown in Table II. The composition of the base glass was computed as 71.1 per cent SiO_2, 0.6 per cent Al_2O_3, 0.14 per cent MgO, 12.3 per cent CaO, 0.07 per cent MnO (or equivalent Mn_2O_3), 0.09 per cent S, 13.9 per cent Na_2O. The batches are given in Table III.

Some of the results shown in Table III are illustrated in Fig. 1, Glasses A to H. They may be summarized as follows, assuming that the pale green tints are due to iron.

a.—The amber color caused by the use of 5 per cent slag may be prevented by introducing 4 to 5 per cent ZnO in the glass. This action of ZnO may be explained on the assumption that these zinc oxide glasses are able to hold small quantities of sulfides in solution.

b.—The use of 0.4 per cent of arsenic oxide destroys the amber color, probably by oxidation of sulfur at high temperatures.

c.—Antimony oxide has a similar decolorizing action to that of arsenic.

GEORGE S. BACON RETIRES

Culminating a distinguished career of 58 years of service in the glass industry, George S. Bacon recently resigned his position with the Armstrong Cork Company at their glass plant in Millville, N. J. Previous to joining the Armstrong organization, Mr. Bacon had been associated with the Whitall Tatum Company for 57 years previous to its absorption by the former company.

Mr. Bacon joined the Whitall Tatum Company in 1881 as an office boy in the firm's Philadelphia office and was rapidly promoted, becoming manager of the company's Green Works in Millville in 1892. In 1897, he became general manager of both of Whitall Tatum's plants, joined the board of directors in 1910 and became a vice-president in 1936.

In 1895, under his direction the Whitall Tatum Company began making flint glass in a day tank furnace. He is also reported to have been instrumental in bringing about the construction of the first continuous tank furnace for making flint glass.

In addition to his achievement as an engineer, Mr. Bacon served continuously as a member of the wage committee of the National Bottle Manufacturers Association from 1895 to 1925, and has been a director of the Glass Container Association since its founding. He also served as vice-president, chairman of the managing committee, and as secretary of GCA.

PRODUCTION FIGURES FOR THE GLASS INDUSTRY DURING APRIL, 1939

Window Glass: During April, 1939, the production of window glass was 739,951 boxes which represents 45.6 per cent of industry capacity. As compared with this, April, 1938, production was 341,014 boxes, representing 21.0 per cent of industry capacity.

Plate Glass: The production of polished plate glass by member companies of the Plate Glass Manufacturers of America during April, 1939, was 7,268,068 sq. ft. as compared to 11,886,817 sq. ft. produced in the preceding month, March, 1939, and 3,819,735 sq. ft. produced in April, 1938.

Glass Containers: Production of glass containers during April, 1939, was 4,071,026 gross bringing the 1939 total to 15,158,101 gross. Shipments during April were 3,978,403 gross, bringing the 1939 total to 14,689,289 gross.

CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

Base Materials

		Carlots	Less Carlots
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	43.00	46.00
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Borax ($Na_2B_4O_7 10H_2O$)	lb.	....	....
Granulated	In bags, lb.	.0215	.027 -.0295
Powdered	In bags, lb.	.024	.0295-.032
Boric acid (H_3BO_3) granulated	In bags, lb.	.048	.054 -.0565
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07½
Cryolite ($Na_3Al\ F_6$) Natural Greenland (Kryolith)	lb.	.0865	.0925
Synthetic (Artificial)	lb.	.0825	.0875
Feldspar—			
20 mesh	ton	11.00-13.25	
40 mesh	ton	11.50-13.75	
Granular	ton	11.75-14.00	
Semi-granular	ton	11.00-13.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags			
Fluorspar (CaF_2) domestic, ground, 96-98% (max SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	29.00	....
In bags	ton	30.60	40.00-42.00
Kryolith (see Cryolite)			
Lead Oxide (Pb_3O_4) (red lead) (N. Y.)	lb.	.0725	....
In 5 Ton lots	lb.	....	.0775
Less than 5 Tons	lb.	....	.0825
Lime—			
Hydrated ($Ca(OH)_2$) (in paper sacks)	ton	8.50	8.50
Burnt (CaO) ground, in bulk	ton	7.00	....
Burnt, ground, in paper sacks	ton	9.00	9.00
Burnt, ground, in 180 lb. drums	Per drum	1.60	1.70
Kiln Dried ($CaCO_3$) 10x30 mesh	ton	1.75	....
Kiln Dried ($CaCO_3$) 16x120 mesh	ton	1.75	....
Nepheline Syenite, f. o. b. shipping point	ton	12.00-14.00	....
Potassium carbonate—			
Calcined (K_2CO_3) 96-98%	lb.	.065	.0675
Hydrated 80-85%	lb.	.055	.0575
Salt cake, glassmakers (Na_2SO_4)	ton	15.00	25.00
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb.	.95	....
In barrels	Per 100 lb.	1.35	....
In bags	Per 100 lb.	1.10	....
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls.	Per 100 lb.	....	2.50-2.90
95% and 97%			
Bulk	Per 100 lb.	1.35	....
200 lb. bags		1.415	1.44
100 lb. bags		1.45	1.475

Special Materials

		Carlots	Less Carlots
Aluminum hydrate (Al $(OH)_3$)	lb.	.029	.03⅓
Aluminum oxide (Al_2O_3)	lb.	.07	.09
Antimony oxide (Sb_2O_3)	lb.	.11	.11¾
Arsenic trioxide (As_2O_3) (dense white) 99%	lb.	.03	.03⅓
Barium nitrate ($Ba(NO_3)_2$)	lb.	....	.07¾
Pyrophyllite, (20% Al_2O_3)	ton	9.00	12.00
Sodium fluosilicate (Na_2SiF_4)	lb.	.035-.04	.04¼-.05
Tin Oxide (SnO_2) in bbls.	lb.	....	.52
Titanium Oxide (ceramic grade)			
In bags	lb.	.12¼	.12½-.13
In barrels	lb.	.12½	.12¾-.13¼
Zinc Oxide (ZnO)			
American process, Bags	lb.	.06¾	.06½
White Seal, 150 lb. bbls.	lb.	.08¾	.09
Green Seal bags	lb.	.08	.08¼
Domestic White Seal bags	lb.	.08½	.08¾
Red Seal, bags	lb.	.07½	.07¾
Zircon			
Refined Granular (Milled .01-.02c higher)		.06½	.07-.08
Commercial, Gran. (Milled .01¼-.01½ higher)		.0275	.0325

Coloring Materials

		Carlots	Less Carlots
Barium selenite ($BaSeO_3$)	lb.	....	1.40-1.60
(Commercial, 25% Selenium)	lb.	....	.85
Cadmium sulphide (CdS)	lb.	....	70-.75
Chromite (99% through 200 mesh)	ton	35.50	40.00
Chromite ore (air floated)	ton	55.00	58.00-73.00
Cerium hydrate—			
100 lb. drums and 600 lb. barrels	lb.	....	.60
Chrome Oxide Green, 400 lb. bbls.	lb.	....	.22-.26
Cobalt oxide (Co_2O_3)			
In bbls. 350 lbs. or more,	lb.	....	1.67
Less than 350 lbs.,	lb.	....	1.77
Copper oxide—			
Red (Cu_2O)	lb.	....	.165
Black (CuO)	lb.	....	.16-.17
Black prepared	lb.	....	.22
Iron Oxide—			
Red (Fe_2O_3)	lb.	....	.0425-.09
Black (Fe_3O_4)	lb.	.04½	.09
Iron Chromate	lb.	....	.035-.05
Lead Chromate ($PbCrO_4$) in bbls.	lb.	....	.145
Manganese, Black Oxide			
In Paper bags	ton	47.50	50.50-54.50
In Burlap bags	ton	49.25	51.75-56.75
In Casks	ton	51.50	54.00-59.00
Neodymium oxalate, 50 lb. drums	lb.	....	3.50
Nickel oxide (Ni_2O_3), black	lb.	....	.35-.40
Nickel monoxide (NiO), green	lb.	....	.35-.37
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals	lb.	.08¾	.09-.09¼
Powdered	lb.	....	.09½-.09¾
Potassium Chromate (K_2CrO_4) 100 lb. kegs	lb.	....	.27
Powder blue	lb.	....	.17-.2125
Rare earth hydrate—			
100 lb. drums	lb.	....	.35
325 lb. barrels	lb.	....	.30
Selenium (Se) In 100 lb. lots	lb.	....	1.75
In lesser quantities	lb.	....	1.85
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.06¾	.07-.07¼
Sodium chromate (Na_2CrO_4) Anhydrous	lb.	.08⅜	.08¾-.08¾
Sodium selenite (Na_2SeO_3)	lb.	....	1.50-1.65
Sodium uranate (Na_2UO_4) Orange	lb.	....	1.75-1.80
Yellow	lb.	....	1.75-1.80
Sulphur (S)—			
Flowers, in bbls.	Per 100 lb.	3.35	3.70-4.10
Flowers, in bags	Per 100 lb.	3.00	3.35-3.75
Flour, heavy, in 250 lb. bbls.	Per 100 lb.	2.90	3.25-3.65
Uranium oxide (UO_2) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	....	2.65-2.75
Yellow orange	lb.	....	1.75-1.80

Polishing Materials

		Carlots	Less Carlots
Emery, Turkish	lb.	.063	.07
Pumice Stone,			
American Ground Italian FFF, FF, F	lb.	....	.03
0, 0½, ½, 1.	lb.	....	.03¼
Putty Powder	lb.	....	.38-.42
Rotten Stone, (Domestic)	lb.	....	.02
Rouge, Red	lb.	....	.14
Black	lb.	....	.16

LUMINOUS FLAME AND ITS APPLICATION

In a paper presented recently before the Industrial Gas Section of the American Gas Association, James E. Dare, Public Service Co. of Northern Illinois, discussed the general application of luminous flame for industrial heating purposes, including its use in the glass plant for melting, refining, annealing and mould heating. Among the advantages mentioned by Mr. Dare as being offered by the proper use of the luminous flame are (1) an increased rate of heat transfer, (2) more uniform temperature control, (3) less maintenance of furnace refractories, (4) greater degree of turn-down of burners, (5) formation of scale which requires less effort to remove and reduction in the amount of scale (metal heating).

For luminous flame applications furnaces should be constructed to minimize air infiltration which causes turbulence and pre-combustion. Also this type of combustion should be applied where a short flame cannot distribute the heat properly, as in large glass tanks, and the heating of glass, where the radiant energy of the luminous flame will penetrate to a greater extent than the energy produced by a non-luminous flame, offers an ideal application.

In general, the fundamental design of standard luminous-flame burners includes a method of controlling the amount of primary and secondary air admitted at the burner. This is accomplished in any one of the following ways, depending on the type of burner:

1. Through the use of concentric rings inside the main burner body, the type of flame being controlled through manipulation of a flame control adjusting nut. 2. Through the ultilization of a rotary air valve provided with two ports, one supplying the primary air and one the secondary air. 3. Through the use of a control gas, the function of which is to permit control of the velocity of the gas stream and its burning characteristics. 4. Through the use of concentric rings for admitting air progressively to the outside boundaries of the gas stream and cracking a small amount of the air-gas mixture within the burner itself by means of a special ignition burner.

Available burners are capable of producing satisfactory luminous combustion with gases ranging from blast-furnace gas of 350 B.T.U. per cu. ft. to natural gas of 1,500 B.T.U. per cu. ft. Propane or butane can also be used satisfactorily as a standby fuel.

The success of luminous-flame burners for heating glass tanks depends almost entirely on the location of the gas inlet pipes or burner blocks and the port design. Where low pressure gas is used, it is introduced into the air stream at right angles behind a protection block or baffle that decreases turbulence in the gas stream. With gas at higher pressure the burner blocks should be so arranged that the gas is introduced into the sides of the air stream at an angle of approximately 45 degrees.

The cross-sectional area of the port is very important and should be determined from the volume and velocity of the gas-air mixture that is to pass through it. It is then necessary to determine the ratio of width to height. If the nose of the port is too wide, it will be difficult to control the position and direction of the flame, while if the port is too high and narrow, the bottom of the flame will be smoky and combustion will not be completed in the hearth.

The slope of the port roof is also important and should be sufficient to direct the flame close to the glass, but not too steep or the flame will spread and be deflected by the charge towards the crown of the furnace.

In conclusion Mr. Dare stated that the advantages mentioned could be secured with luminous combustion only when the application for luminous firing is properly selected and designed. In general any gas heating problem can be solved to a certain degree with either luminous or non-luminous combustion, but if all conditions are carefully analyzed, one specific type will usually be found to meet best the particular requirements of the installation.

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● Paul F. Wacker, an Ohio State University graduate, has joined the staff of Battelle Memorial Institute, industrial research organization of Columbus, Ohio. He has been assigned to the ceramic division, which does research work in all fields of ceramics. Mr. Wacker is a member of the American Chemical Society, the American Ceramic Society, American Association for the Advancement of Science, and Sigma Pi Sigma.

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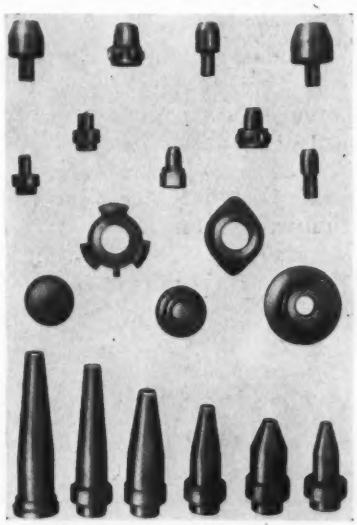

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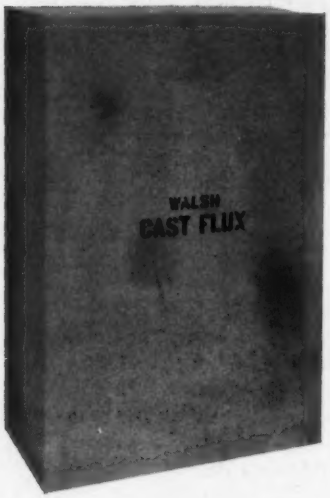

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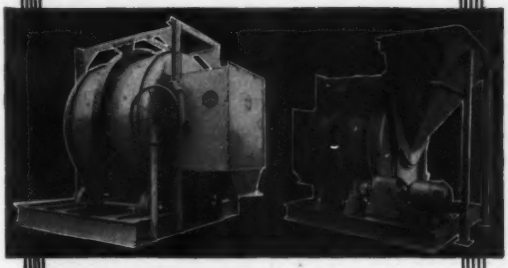

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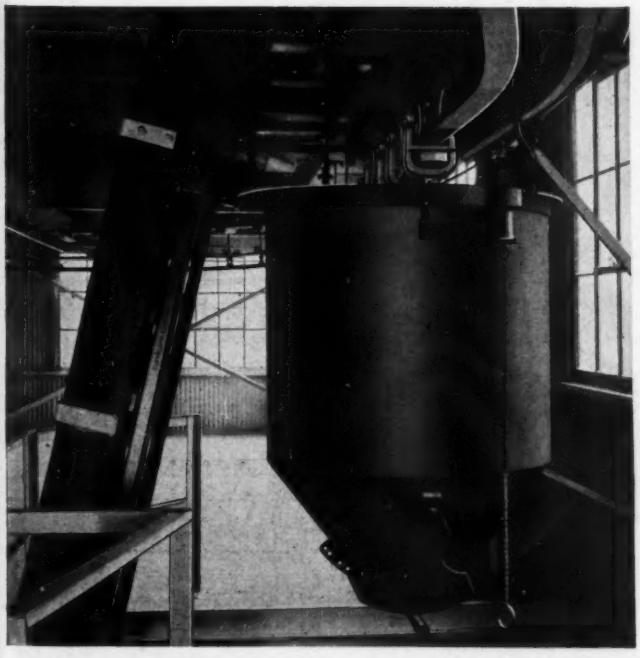

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